THE *MAYFLOWER* PROBLEM

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Given to L. W. Fulong by his friend, William Baker

Reprinted from *The American Neptune*
Vol. XIV, No. 1, 1954

Printed by The Anthoensen Press, Portland, Maine

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IN the maritime history of this country there have been many famous vessels, vessels whose names bring to mind tales of exploration, colonization, merchant ventures, and desperate sea battles. There are varying opinions as to which is the most important, but one that stands high on the list is a small English merchant ship about which little is known. This vessel brought to these shores in 1620 the little band of dissenters and those who, for various reasons, cast their lot with them, now known as the Pilgrims. From the usual listings in the catalogues of large libraries one might infer that there exists a wealth of data on this vessel; actually the only seemingly reliable information concerns the voyage, and even that is scant.

The generally accepted reliable source of information on the voyage is Bradford's *Of Plimoth Plantation*.[1] This work traces the developments leading to the chartering of two vessels by the group of dissenters living in Holland, the voyage to England, the difficulties encountered by the smaller vessel and the subsequent embarking of part of her complement on the larger, the voyage to North America, the arrival in this country, and the events leading to the final landing at Plymouth. Yet Bradford does not name or give the dimensions of either vessel. Although the voyage to North America was a decisive move for the colonists, it was but another in a long series of fishing and trading voyages for the seamen involved, not worthy of special note.

The two vessels were merely common traders, the larger chartered for one voyage while the smaller was to have remained with the colonists to be used in fishing and for trading along the coast. Bradford gives two items of information concerning the size of the larger vessel, one negative and one positive. The negative is that she was not as large as the group desired and the positive that her burden was about nine score;

1 William Bradford, *Of Plimoth Plantation,* printed by order of the General Court (Boston: Wright & Potter Printing Co., State Printers, 1899). Hereafter called General Court Edition.

nine score what will be discussed later. It was not until 1623 that a reference is made in the records of the Colony to those 'which came first over in the May-Flower,' and thus her name is known. The name of the second, *Speedwell,* is first mentioned by Morton.[2]

The fact that *Mayflower* was a common name for merchant vessels in the early seventeenth century has made it difficult to uncover any definite material on this particular vessel. Because of references to leaky topsides and the cracking of a beam during a storm, it is generally assumed that the Pilgrims' *Mayflower* was an old vessel when she made her now famous voyage in 1620. Considering the resources of those involved, it is possible that the chartering of a newer vessel might have been beyond them. It seems unlikely at this late date that any definite information regarding her age will ever be found, but a few assumptions and deductions have led to some interesting data on a vessel that might have been THE *Mayflower.*

From Bradford's journal and a certified copy of William Mullins' will[3] it has been deduced that the master of *Mayflower* on her voyage to this country was one Christopher Jones. Through the records of the Port of London it has been possible to trace the voyages of a *Mayflower,* Christopher Jones, Master, from August 1609 to October 1621, during which period there is a gap that would allow for the round-trip voyage to North America.[4] From a series of neighborly relationships and ship commands too lengthy to review here, a shaky claim has been made that the Pilgrim *Mayflower* was one of the two *Mayflower*s in the English fleet that defeated the Spanish Armada in 1588.[5]

The last entry in the London Port Books relating to the Christopher Jones *Mayflower* is dated 31 October 1621 when she unloaded salt from Rochelle; the last record of her master is in the register of St. Mary's, Rotherhithe, for 1621/2: 'Christopher Jones, buried 5 March.' He left no will and his widow, Joan, was granted a commission of administration. In 1624, acting on a petition by Mrs. Jones and two of three other part owners that described *Mayflower* as 'in ruinis,' the High Court of Admiralty appointed four surveyors who valued the vessel at £128 8*s* 4*d*. Her ultimate fate is unknown. Claims have been made that a barn in Buckinghamshire was constructed from her timbers and that her masts served

[2] Nathaniel Morton, *New England's Memoriall* (Boston, 1669).

[3] William Mullins' will filed in Somerset House, London. File reference 68 Dale, ff. 68, 69.

[4] J. R. Hutchinson, 'The *Mayflower,* Her Identity and Tonnage,' *New England Historical and Genealogical Register,* 70 (1916), 337-342.

[5] R. G. Marsden, 'The *Mayflower, The Mayflower Descendant,* XVIII (January 1916), 1-13.

as pillars for the Independent Chapel at Abingdon. Neither of these claims have been proved to the satisfaction of competent researchers.[6]

None of the investigators to date have found any record of *Mayflower*'s dimensions. The only indications of her size are the aforementioned burden of nine score stated by Bradford and similar figures which have been assumed to apply to the same vessel as given by other writers. The smallest of these figures is that given in a letter from Robert Cushman to the group in Holland.[7] He refers to the chartering of a vessel of 60 lasts[8] but it is now assumed that he was reporting on earlier negotiations than those which resulted in the chartering of *Mayflower*. A published note by the Earl of Southampton[9] listing the vessels sent to America in 1620 by the Virginia Company mentions a *Mayflower* of 140 tons. Next in size is Captain John Smith's reference to a ship of 'a hundred and three score tunnes.'[10]

Bradford's figure of nine score is open to two interpretations. Since he was writing about a vessel chartered in England it would seem logical that he was referring to the English unit of measure—the ton. On the other hand, it has been suggested that his residence in Holland might have led to his use of the Dutch unit—the last. However, the consensus is that the nine score was the burden of *Mayflower* in English tons. While many have marvelled that so small a ship could have transported the 104 passengers plus crew, the records of similar voyages during the early seventeenth century indicate that she was not unduly crowded. For example, *Margaret and John* of 150 tons carried 85 passengers, and *Abigail,* 350 tons, had 230 passengers.

Such a variation in tonnage is slightly confusing, but tonnage always has been confusing and still is. A record in the London Port Books helps a little to clarify the problem, assuming, of course, that the Christopher Jones *Mayflower* is the one in which we are interested. On the 28th, 29th and 31st of January 1620, she unloaded 153 'tonnes of French wynes,' 4 'tonnes redd wyne' and 16 hogsheads of French wines. With 4 hogsheads equalling one ton this lading adds to 161 tons, which seems to check Captain John Smith's 160 tons but rules out the 140 in the Earl of Southampton's note.[11] On the other hand, it seems reasonable to assume that a

[6] J. W. Horrocks, 'The Mayflower,' *The Mariners' Mirror,* VIII (1922). A lengthy article in several parts.

[7] Bradford, General Court Edition, p. 67.

[8] One last equalled about two English tons.

[9] Earl of Southampton, *A Note of Shipping Provided for Virginia,* 1620 (Duke of Manchester's Papers, No. 121), discussed by Hutchinson, *New England Historical and Genealogical Register.*

[10] Captain John Smith, *The Generall Historie of Virginia, New England and the Summer Isles.*

[11] A discussion of tonnage rules to follow will clarify this statement.

prudent skipper would not cram his vessel full for a midwinter voyage, hence Bradford's 180 is acceptable.

Since the burden is the only information regarding size, a study of the English tonnage rule and proportions of ships of the period will lead to a range of possible sizes if nothing more. The English tonnage rule of 1582, which was in use during the assumed life of the Pilgrims' *Mayflower,* was formulated by a Master Shipwright of the first Queen Elizabeth, one Mathew Baker. The purpose of the rule was to set up a formula based on the basic dimensions of a ship which would give a figure equal to the number of tons of wine that a ship was able to stow. One statement of the rule is as follows:[12]

> By the proportion of breadth, depth and length of any ship to judge what burden she may be of in merchant's goods and how much deadweight of tons and tonnage. The *Ascension* of London being in breadth 24 feet, depth 12 feet from that breadth to the hold, and by the keel 54 feet in length doth carry in burden of merchant's goods (in pipes of oil or Bordeaux wine) 160 tons, but to accompt her in deadweight, or her ton and tonnage may be added one third part of the same burden which maketh her tonnage 213 1/3.

Here we must resort to a bit of mathematics to boil the above down to a simple formula. To arrive at *Ascension*'s burden of 160 tons the product of her three dimensions 54 x 24 x 12, which in round numbers is 15,500, must be divided by 97. So, representing the length of keel, breadth and depth by the letters K, B and D, the formula for the burden becomes K x B x D/97. But, Mathew Baker's own notebook indicates that the divisor should be 100, so we have K x B x D/100 as the official rule. The discrepancy of five tons between 54 x 24 x 12/100 and the recorded burden of 160 may be caused by the omission of odd inches when setting down the dimension of *Ascension* or it may be that she actually stowed 160 tons.

Now it is necessary to determine just how the three basic dimensions were measured. The length of the keel was the straight portion that would lie on keel blocks or touch on the ground measured from the afterside of the main sternpost to the intersection of the stem and the keel. Inasmuch as the lower stem of Elizabethan ships was usually an arc of a circle coming in tagent to the keel, the exact forward end of the keel would have been difficult to determine. The breadth was measured at the widest part of the hull to the inside of the planking, i.e., the maximum molded breadth, and the depth was measured from this point to

[12] M. Oppenheim, *A History of the Administration of the Royal Navy and of Merchant Shipping in Relation to the Navy* (London and New York: John Lane, The Bodley Head, 1896), p. 132.

the top of the keel. Because of the difficulties in reaching these points of measurement after a ship was completed, it became more or less common practice to measure the maximum breadth to the outside of the planking and the depth to the bottom of the keel.

A single thickness of planking on the breadth might not have made too much difference in calculating the burden, but if a ship proved to have insufficient stability, the shipwrights added one or more layers of planking on the outside in way of the waterline. This was termed furring or girdling, and during the period in question the English had the reputation of having more furred ships than any other nation. By measuring to the outside of this furring the value for the burden was such that a charterer was getting far less usable volume in a ship than the burden indicated. The situation became so bad, particularly with ships hired for royal service, that in 1627 a commission was appointed to investigate tonnage measurement and to devise a satisfactory rule. The commissioners were not equal to the task of accurately calculating the actual internal volume of a ship and, after considering the various methods used in taking the measurements, finally confirmed the use of the old rule of 1582 for ships built or hired for the King's service—K x B x D/100.[13]

It is interesting to note that the depth was not measured from a deck line as became the practice later. This is a result of the fact that during the late sixteenth and early seventeenth centuries shipbuilders had no tradition of a continuous deck running fore and aft to hamper their arrangement of a ship. The hull was usually considered in three sections, bow, waist and stern, with the deck levels in each arranged as necessary to suit the space requirements.

As for the proportions of ships, the reign of Queen Elizabeth I saw the first ships being built specifically for merchant service. Merchant vessels were still armed for protection against pirates and others on the high seas but carried fewer cannon than similar sized vessels of the Royal Navy. Up to this time there had been little difference between vessels of the merchant and royal navies except that perhaps the men-of-war were constructed somewhat stronger. Royal vessels had been chartered by prominent merchants for certain voyages and ordinary merchant vessels were hired for royal service. Of the 197 English vessels that opposed the Spanish Armada, only 34 were royal ships, the remainder being merchant vessels of all sizes, the largest being 400 tons and the smallest 30 tons.

It is a common fallacy to consider ships of this period quite tubby. This comes from comparing published dimensions listing the keel length

[13] Ibid., p. 268.

of these ships with the length on the gun deck that was commonly used for later vessels. To obtain a better comparison the sum of the forward rake of the stem and the after rake of the sternpost, usually equal to the breadth, should be added to the keel length. Actually, naval vessels of a century later were fuller than those of the Elizabethan era because the increases in armament required more displacement in the ends.

William Borough, Comptroller of the Navy from 1589 to 1598, listed the following proportions for the vessels of his time:[14]

1. The shortest, broadest and deepest order—To have the length by the keel double the breadth amidships and the depth in hold half that breadth. This order is used in some merchant ships for most profit.
2. The mean and best proportion for shipping for merchandise likewise very serviceable for all purposes. Length of keel two or two and a quarter that of beam. Depth of hold eleven-twentyfourths that of beam.
3. The largest order for galleons or ships for the wars made for the most advantage of sailing. Length of keel three times the beam. Depth of hold two-fifths of beam.

Unfortunately, the only tables of dimensions for ships of the period are concerned largely with vessels of the Royal Navy, but by eliminating the larger vessels and known galleys from consideration the proportions of the remaining ships should be typical of the average merchantman-warship combination. Table I[15] lists the three basic dimensions, the length-breadth ratio, the depth-breadth ratio and the burden, calculated as K x B x D/100, for a number of moderate-sized ships of about the 180 tons burden of *Mayflower*.

TABLE I

Name	*Date*	*Length of Keel—Ft.*	*Breadth Ft.*	*Depth Ft.*	*L/B*	*D/B*	*Burden*
1. *Prudence*	*ca.* 1582	51.5	24	12	2.14	.500	148
2. *Ascension*	*ca.* 1582	54	24	12	2.25	.500	156
3. *Crane*	1590	60	26	13	2.31	.500	202
4. *Quittance*	1590	64	26	13	2.46	.500	217
5. *Answer*	1590	65	26	13	2.50	.500	219
6. *Advantage*	1590	60	24	12	2.50	.500	173
7. *Tremontana*	1586	60	22	10	2.73	.454	132
8. *Phoenix*	1612	70	24	11	2.92	.458	185
9. *Mary Rose*	1623	83	27	13	3.07	.482	291
10. *Adventure*	*ca.* 1627	63.6	26.2	11	2.42	.420	183

Since the statement of the 1582 tonnage rule used *Ascension* as an example it may safely be assumed that she was a merchant vessel—note that

[14] Ibid., p. 126.

[15] Ibid., pp. 124 and 132.

her proportions are nearly those of Borough's second order. Although *Crane* was built by one R. Chapman, her exact dimensions were used by Mathew Baker in demonstrating a problem of comparative burdens. *Adventure* was definitely a merchant vessel and she was used as an example for the 1627 tonnage survey previously mentioned.

Table II lists the dimensions and proportion of certain unnamed vessels taken from manuscript sources, three from Baker's notebook[16] and two from an anonymous treatise on shipbuilding compiled about 1600.[17]

TABLE II

Source	*Length of Keel—Ft.*	*Breadth Ft.*	*Depth Ft.*	*L/B*	*B/D*	*Burden*
1. M. Baker A	45	20	10	2.25	.500	90
2. M. Baker B	48	20	10	2.40	.500	96
3. M. Baker C	60	24	12	2.50	.500	173
4. Anon. MS. A	72	24	10	3.00	.417	173
5. Anon. MS. B	85	25	9	3.40	.360	191

From the context of the material in Mathew Baker's notebook it is assumed that the three vessels listed in Table II are merchantmen. Items 4 and 5 taken from the anonymous MS. are respectively a 'marchauntt man' and a 'man of warr.'

To give a range of possible sizes for *Mayflower,* Table III has been compiled for a ship of 180 tons burden based on the data given by Borough and the proportions of the vessels listed in Tables I and II, omitting those which would produce duplicate sizes.

TABLE III

Source	*L/B*	*D/B*	*Length of Keel—Ft.*	*Breadth Ft.*	*Depth Ft.*
Borough—1st order	2.00	.500	52.4	26.2	13.1
—2nd order	2.00	.458	54.0	27.0	12.4
—2nd order	2.25	.458	58.4	26.0	11.9
—3rd order	3.00	.400	74.1	24.7	9.9
Prudence	2.14	.500	54.8	25.6	12.8
Ascension	2.25	.500	56.7	25.2	12.6
Crane	2.31	.500	57.7	25.0	12.5
Quittance	2.46	.500	60.2	24.5	12.3
Answer	2.50	.500	60.8	24.3	12.2
Tremontana	2.73	.454	66.6	24.4	11.1

[16] Mathew Baker's Notebook, Pepys 2820, Magdalen College Library. By courtesy of the Cambridge University Library.

[17] Anonymous MS., *A Most Excellent Mannor for the Building of Shippes,* Scott Collection, Institution of Naval Architects, London. By courtesy of the Institution of Naval Architects, London.

Phoenix	2.92	.458	69.5	23.8	10.9
Mary Rose	3.07	.482	70.6	23.0	11.1
Adventure	2.42	.420	63.1	26.1	11.0
M. Baker—B	2.40	.500	59.2	24.7	12.4
Anon. MS.—A	3.00	.417	73.0	24.3	10.1
—B	3.40	.360	83.3	24.5	8.8

Thus we see that, considering the known merchant vessels, *Mayflower* could have had a keel length anywhere between 52.4 feet and 73.0 feet, a breadth from 24.3 feet to 27.0 feet and a depth of 10.1 feet to 13.1 feet. The reader may make his choice.

Turning now to a consideration of the appearance of *Mayflower,* one finds little agreement among marine archaeologists. A survey of the many etchings, models, paintings and what-have-you purporting to be this vessel reveals some startling representations—one etching depicts the square sails set on the after sides of the masts. Bradford is of little help; the only concrete item is the inference that she carried a main topsail—'. . . he caught hould of ye top-saile halliards, which hunge over board. . . .'[18]

A footnote in the Massachusetts Historical Society's edition of Bradford states:[19]

> No description or representation of the *Mayflower* other than the brief references in Bradford exists. There is, however, no reason for believing that she differed materially from the merchant vessels of that day, or that an English vessel of her class differed materially from a merchant vessel of any other commercial people of Europe. The map makers of that period almost invariably drew upon some part of their plate one or more vessels, usually of the trading types with sails set, and threading their way among the monsters of the deep, often much larger than themselves. Whether the map was English, Dutch, or German, the vessels have the same general appearance.

While for the size of sketch that would appear on a map the above is generally true, that were certain national characteristics in proportions, form, and rig that were dictated by the coastal conditions of the various countries. For example, the shallow waters off the Netherlands led to the development of bluff, beamy vessels of restricted draft while the English harbors permitted the use of deeper, narrower ships. Details of decoration also varied considerably. Still, printed and manuscript sources indicate a considerable exchange of shipbuilding knowledge, and when considering miscellaneous items of equipment it does not seem unreasonable to use whatever data is available regardless of nationality. If a ship

[18] Bradford, General Court Edition, p. 92.

[19] William Bradford, *A History of Plymouth Plantation, 1620-1647* (Boston: Massachusetts Historical Society, 1912), p. 148.

received damage at sea, the repairs undoubtedly would have been effected in whatever manner was standard in the next port visited; thus a vessel could have been equipped with items from many countries.

While certain technical material concerning ships of the late sixteenth and early seventeenth centuries is available, much of our knowledge of these vessels comes from old engravings, etchings and paintings. Such information is dubious at best as it is the result of two interpretations—the artist's interpretation of a ship and our interpretation of his efforts. Some representations seem quite reasonable—others the products of the weirdest possible nightmares. When one tries to find data on the appearance and construction details of any particular vessel the problem is well-nigh hopeless.

It would be foolhardy to try to discuss the multitude of artistic representations of *Mayflower;* the variations in size, shape and rig are amazing. Perhaps one should not complain for, had photography not been invented, the marine archaeologists of two hundred years hence might well wonder at the accuracy of the many pretty ship pictures labelled *Flying Cloud, Constitution,* etc. The majority of the artists should have followed the advice given to one modern artist who wanted to portray the little fleet of Columbus at sea—show *Santa Maria* in the distance to eliminate the need for many details and put the other two ships over the horizon. (The source of this story has slipped from memory—my apologies to its author for use without acknowledgment.)

Turning to more concrete representations of *Mayflower,* there are several model versions and one partial reconstruction. One of the best-known models is that in the Smithsonian Institution, Washington, D. C., replicas of which may be seen in many places. Representing a vessel of 120 tons—evidently based on the data in Cushman's letter—it was designed and built by Captain Joseph W. Collins. His details were developed from material shown by Admiral Paris in his *Souvenirs de Marine.*

Using Bradford's 180 tons as a basis for size, the late Professor James R. Jack designed and built in about the year 1925 the model that is now in the Francis Russell Hart Nautical Museum at the Massachusetts Institute of Technology. In 1928, Professor F. Alexander Magoun published plans for a model[20] that is essentially Professor Jack's but with certain features modified by the work of Dr. Anderson noted below. The model in the new Science Museum in Boston appears to have been built from these plans.

20 F. Alexander Magoun, *The Frigate Constitution and Other Historic Ships* (Salem: Marine Research Society, 1928).

At about the same time that Professor Jack was designing his model of *Mayflower* and using the 180 tons as a basis, Dr. R. C. Anderson and Mr. L. A. Pritchard were designing and building in England the model that is now on display in Pilgrim Hall, Plymouth, Massachusetts. A smaller model to the same design was constructed for the Addison Gallery of American Art, Phillips Academy, Andover, Massachusetts.

Metro-Goldwyn-Mayer produced a version of *Mayflower* in two sizes for the film *Plymouth Adventure*. A large sailing model was built for scenes showing the vessel at sea and a full size partial reconstruction for the deck shots. This version appears to have been largely based on Dr. Anderson's work.

Since Captain Collins' model in the Smithsonian Institution represents a vessel of but 120 tons it can be eliminated from further discussion except to note in passing certain features that have drawn comments from marine archaeologists. These features are enclosed quarter galleries, no bulwarks in the waist, pole masts, and long topsail yards.

When quarter galleries were fitted on small ships of the period, and judging from old prints that was seldom, they were nothing more than open balconies, if such a landlubberly term may be used. The majority of old prints show that vessels of the general size and type of *Mayflower* usually had fairly solid bulwarks, sometimes with a shallow open rail on top.

While older small vessels may have had lower and topmasts in one piece, the consensus seems to favor separate topmasts for *Mayflower*. Many otherwise acceptable models and artistic representations of ships of the period have been spoiled by having over-long topsail yards. The usual length was one-half the length of the lower yard, and one authority quotes the proper length as three-sevenths of the lower yard.

In a brochure describing various models in the Francis Russell Hart Nautical Museum, Professor Jack says of his model of *Mayflower*:[21]

> Many attempts have been made to produce models of the type and time of the *Mayflower* and of these the most reliable are a half-inch scale model . . . and a quarter-inch scale model . . . , both of which have been built under the direction of Mr. R. C. Anderson.
>
> The Institute's model was made a little earlier than these and therefore did not have the advantage of Mr. Anderson's painstaking research, although the sail plan and rigging correspond fairly closely.

The dimensions as scaled from the plans in Professor Magoun's book are: length of keel 72 feet, breadth 26 feet and depth 9 feet 6 inches.

[21] James R. Jack, *Some Historic Ships and Their Models* (Cambridge: Massachusetts Institute of Technology, 1941), p. 27.

As for Dr. Anderson's model, it is best to use his own words as published in the *Mariners' Mirror* for 1926:[22]

... When I was asked to prepare a design for a model of the *Mayflower* I was obliged to say that to the best of my knowledge such a thing is impossible, though I could produce a model of a ship of about the right size and type. This I hope I have managed to do, but it must be clearly understood that the model makes no claim to be more than it is called on its label, an 'English merchantman of the size and date of the *Mayflower.*'

For dimensions the *Adventure* of Ipswich was a perfect godsend. She was used in 1627 to illustrate the results of various methods of tonnage measurement. ... On 'Mr. Baker's Old Way' she was 182 tons, while her dimensions were: Length of keel 63 feet, 6 inches, greatest breadth within the plank 26 feet, 2 inches, depth from the breadth to the top of the keel 11 feet. Avoiding odd inches I made the ship 64 feet by 26 feet by 11 feet, and by giving her a total rake forward and aft of the same amount as her beam, 26 feet, I got a nice round number of 90 feet for her length from stem to sternpost. It is possible that the 180 tons of the *Mayflower* was a 'tons and tonnage' figure; in that case her 'burthen' would have been 25 per cent. less, or 135, and her dimensions would have been about 58 feet by 23½ feet by 10 feet. I think it is more probable that the larger figures are nearer the mark; they give a 'burthen' of 183 tons and a 'tons and tonnage' of 244.

As to rig; there was little doubt that it should be the ordinary three-masted rig of the time. The only question was whether to give her such recent additions as a square mizzen topsail and a spritsail topsail. On the whole it seemed probable that a small and unimportant merchantman would not have had these extra sails. We therefore gave her spritsail, foresail and foretopsail, mainsail and main topsail, and lateen mizzen. ...

In a brochure published in connection with the film *Plymouth Adventure,* Metro-Goldwyn-Mayer summed up the model question and vague ly described their own version in the following words:

Thus all the 'authentic' models of the *Mayflower* to be found in museums and private collections—and there are scores of them throughout the United States—represent little more than the model builder's guess, informed or uninformed and made many generations later, about how the ship looked. ...

Leading historians and marine architects are generally agreed that the *Mayflower* had an over-all length of 90 feet and a broad 24-foot beam, was of approximately 180 tons and probably lateen-rigged on her mizzenmast, being otherwise square-rigged. ...

That was the ship the art department designed—'a chunky little tramp ship of her day,' as she was fondly termed—unquestionably the closest thing to the real *Mayflower* ever built.

Thus, briefly, is the story of *Mayflower,* built from meager knowledge by a few assumptions and much research, and some conjectures and opin-

[22] R. C. Anderson, 'A "Mayflower" Model,' *The Mariners' Mirror,* XII (1926), 260-262.

ions as to her size and appearance. This material was assembled for a background in connection with the preparation of drawings for a proposed replica of an early seventeenth-century English merchant vessel of her size and type. This proposed replica is part of the program of Plimoth Plantation, Incorporated, of Plymouth, Massachusetts, a nonprofit, educational foundation that was organized to preserve and present the heritage of the Pilgrims and which now has two completed projects on display in Plymouth. The first of these, appropriately known as the 'First House,' was built in 1948 and represents the type of house erected by the Pilgrims during their early years in this country. The second project was opened to the public in June 1953 and represents the combined fort and meetinghouse that was erected in 1622.

After studying this background, it is apparent that many researchers have put much time and effort on the problems of the size and appearance of *Mayflower*. The variety of their results makes it impossible to say this or that is right and all else wrong. A new version will owe much to these people and naturally will be influenced by their work.

The primary question to be settled in drawing up plans for the proposed replica is that of dimensions. Using Bradford's tonnage of 180, there is the range shown in Table III. It is tempting to follow Dr. Anderson and accept those of *Adventure* of Ipswich, but two statements made in connection with the tonnage investigation of 1627 raise some doubts as to the reasonableness of such action.

In the body of the tonnage report is the following statement of its purpose: '. . . to measure the *Adventure* of Ipswich, the greatest bilged ship in the river, and from her dimensions to frame a rule that in our best judgments might be indifferently applicable to all kinds of frames.'[23] The masters of Trinity House made the following comment: 'The old rule is less true for lately built ships, which have great floors, but true for old ships with small floors.'[24] From these two statements it can be assumed that the reason for the use of *Adventure* as an example was that she was a new and an unusual ship. Hence, the use of her proportions to represent a merchant ship of some twenty or more years earlier is questionable.

If *Mayflower,* Christopher Jones, Master, of the London Port Books is accepted as the Pilgrims' *Mayflower,* it is known that she was afloat in 1609. A few reasonable assumptions push this date back to February 1606. If she were new at that time, her probable trade and builder would

[23] M. Oppenheim, op. cit., p. 267.

[24] Ibid., p. 268.

have to be considered when discussing proportions—if old, perhaps one of the anti-Armada fleet, there is no way of knowing how far back proportions should be investigated. A common merchant vessel for the lumber and wine trades, in both of which the Christopher Jones *Mayflower* was employed from time to time, would have required as much stowage space as possible. This points toward short length and relatively large breadth and depth for a given tonnage as the internal structure occupies a smaller percentage of the usable space as compared with a longer, narrower, and shallower vessel.

Changes in the proportions and appearance of ships are usually noted first in the larger, more important vessels; in the early seventeenth century these would have been the royal ships. *Mayflower*'s builder would probably have been working in a small yard, building to conservative proportions that had proved successful over a period of years. Assuming *Mayflower* to have been built around the turn of the century, the general increase in the length/breadth ratio of the royal ships might have led him to improve somewhat on Borough's ratios of 2 to 2.25 for merchant ships.

The fact that the dimensions of *Crane,* built by R. Chapman in 1590, are duplicated by an example in Mathew Baker's notebook is an indication that at least two builders of the period were thinking along the same lines. Both of these men built royal ships, and it is probable that their examples would be followed by the common builders within a decade. *Crane*'s burden of 202 indicates that she was of the same general size as *Mayflower,* hence it has been concluded that her proportions are more suitable than those of *Adventure* for a replica of an English merchant vessel of the early seventeenth century.

Crane's proportions—length/breadth ratio of 2.31 with a depth equal to half the breadth—indicate a conservative design of good capacity yet an improvement on Borough. For the proposed replica, eliminating odd inches, the dimensions will be as follows: length of keel 58 feet, breadth 25 feet, and depth 12 feet 6 inches which, by the tonnage rule of 1582, give a burden of 181.

Early Seventeenth-Century Ship Design

By

WILLIAM A. BAKER

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Reprinted from *The American Neptune*
Vol. XIV, No. 4, 1954

Printed by The Anthoensen Press, Portland, Maine

Early Seventeenth-Century Ship Design

BY WILLIAM A. BAKER

WHEN the drawing of the lines plan was started for the proposed *Mayflower* replica to be built by Plimoth Plantation, Incorporated,[1] it was apparent that modern methods of drafting would not properly produce the characteristic shape of vessels of the period. Too many models have been built whose designers have assumed that any round and chunky looking set of lines would do. To determine and understand the methods employed by the Elizabethan shipbuilders it was necessary to survey shipbuilding data over a considerable period of time. Study showed that much of the design procedure was closely allied with the construction and, generally speaking, ships' lines of the period were drawn with no other tools than a straightedge and a compass. Plate 31 shows an Elizabethan shipwright and his apprentice at work on the design of a new ship.

The shape of modern ships is relatively independent of the type of structure employed. Practically any contour can be obtained through the proper use of metals, wood or other materials. The shape of the earliest watercraft was a direct result of the material employed, the first vessel being the log which some early inhabitant of this earth discovered would support him in the water while he paddled along with his hands. One can only surmise the mental processes that led to the securing together of several logs to form a raft on which families and their belongings could be transported and to the hollowing out of the first log canoe. These steps started, early in man's maritime ventures, a parallel development—slow, bulky craft for moving goods, slim, speedy ones for important services and military use, the classic 'round' ship versus the 'long' ship.

The first advance from the hollowed out log canoe came when planks were added to the sides of the canoe to increase its freeboard, thus mak-

[1] For a description of a lines plan and what it represents see Appendix.

ing it more seaworthy and enabling it to carry greater loads. The big step occurred when, needing a vessel larger than the biggest log available, man constructed the first boat entirely of planks. In the course of development such craft long maintained the double-ended shape of the log canoe but it was soon found that by varying the relation between length and breadth, the resultant vessels could be made wide and burdensome or slim and speedy.

There followed centuries of slow progress during which the shape of the ends changed through the requirements of service or fashion, the shape of the midsection departed from the rough semicircle of the log, and decks and superstructures were added. Associated with these changes were the problems of propulsion—oars versus sails. The oar-propelled craft remained long and narrow and almost true double-enders. They were used mainly for military purposes and performed best in the Mediterranean region where voyages were relatively short; the stormy waters of the North Atlantic were very unfavorable. Generally they did carry some sail for use with favorable winds. Sails were the sole means of propulsion for the slow, plodding merchant vessels.

Hybrids in which the builders tried to combine the advantages of oar and sail propulsion were in favor from time to time. In merchant service, the rowers took up much valuable space. In order to carry a sufficient quantity of goods to be economical such vessels had to have considerable displacement which made them too unwieldy for satisfactory propulsion by oars. An exception were the great merchant galleys of Venice which carried relatively light but valuable cargoes of silks, spices, and other products from the East.

As time passed and builders gained experience, rules of thumb were formulated for the proportions of vessels for various services, for structural parts, and for various fittings. These rules were passed along from master builder to apprentice until they were finally set down in writing. Ultimately they appeared in printed form but the first really useful books did not appear until the later half of the sixteenth century. Even then many details were taken for granted. It is impossible today to comprehend some of the design procedures and to know what is meant by certain terms.

The master builders of the great Mediterranean ports took an early lead in the field of naval architecture. This was particularly true in the case of Venice which long held a monopoly on the trade with the East and had organized the famous Arsenal to build and maintain her war

fleets. Many important manuscripts describing the proportions and construction of various types of galleys, round ships, and other craft are preserved in her archives and those of other cities.[2] In England, Samuel Pepys is responsible for saving much material on ships of the Elizabethan period.

It has been said that sailing ships of 1485 differed less from sailing ships of 1785 than they did from those of 1425.[3] Hence, works of about 1450 are as early as need be considered and perhaps those of 1700 are as late as are useful. While a few of the old manuscripts are marked with definite dates, the probable period of composition of others can be determined only from the information they contain. Some may have been written in a relatively short period of time, say by a master shipwright at the instance of a patron. A few may be copies of other works, perhaps only part of a miscellaneous collection on many subjects. But it seems likely that the majority are what might be called notebooks that were compiled over a period of time. Manuscripts of this type present information obtained by the shipwright from others early in his career, data and methods developed during his working years and, finally, his theories and preferences on various subjects.

In studying such old manuscripts and early printed works and making use of the information contained therein, some caution is required in assigning certain details to definite periods. In any art or science there is much material that is carried along from year to year with little or no change and this was particularly true of wooden shipbuilding. Details of design would probably vary from builder to builder; new ships with old features could have been built at the same time as vessels of quite advanced design. Further, frequent rebuildings such as many of the ships of Queen Elizabeth I experienced probably resulted in a mixture of characteristics. All this makes it not unreasonable, when data is missing on certain features of form and construction, to survey the available material and project forward or backward in time as required.

In studying the material pertinent to the design of ships at the beginning of the seventeenth century, a Venetian manuscript dated 1444 was the earliest considered. This is a notebook on many subjects compiled by Giorgio Timbotta containing scattered items on shipbuilding that can be gathered under four headings: 'Galleys,' 'Ships,' 'Rigging,' and

[2] Frederic Chapin Lane, *Venetian Ships and Shipbuilders of the Renaissance* (Baltimore: The Johns Hopkins Press, 1934).

[3] M. Oppenheim, *A History of the Administration of the Royal Navy and of Merchant Shipping in Relation to the Navy* (London and New York: John Lane, The Bodley Head, 1896), p. 40.

'Sailmaking.' There are indications that some of this material was copied from notes of an earlier date but it is considered that the information applied generally to the period 1440-1450.[4]

As might be expected from a Venetian source, the design of galleys is covered in considerable detail but there are also dimensions for eight sailing ships of various sizes. For two of these, there are stem, sternpost, and midsection diagrams and outboard views showing the starboard quarter. There are also data on such items as the position of the mast step, the size of the rudder, and the dimensions of the spars.

Next in time, about a century later, is another Venetian manuscript entitled 'Instructione sul modo di fabricare galerie.' Written by Pre Theodoro de Nicolo, a foreman ship carpenter of the Arsenal, it gives details of shipbuilding practice in the middle of the sixteenth century.[5] Again the various types of galleys are described in detail. There are two new types of vessels mentioned—the oared galleon and the great galleon —and specifications are given for a merchantman indicating that Theodoro had not spent all his career in the Arsenal.

The earliest useful printed work is the *Instrucion Navthica* by Diego Garcia de Palacio published, curiously enough in Mexico, in 1587.[6] This important work is divided into four books, the first three of which, on mathematical and navigational subjects, contain little or no new material, being but compilations from other printed works. But the fourth book contains the first known printed plans of ships and also drawings showing the proper methods of making sails. In addition there is a marine dictionary, perhaps the first in any language to be published.

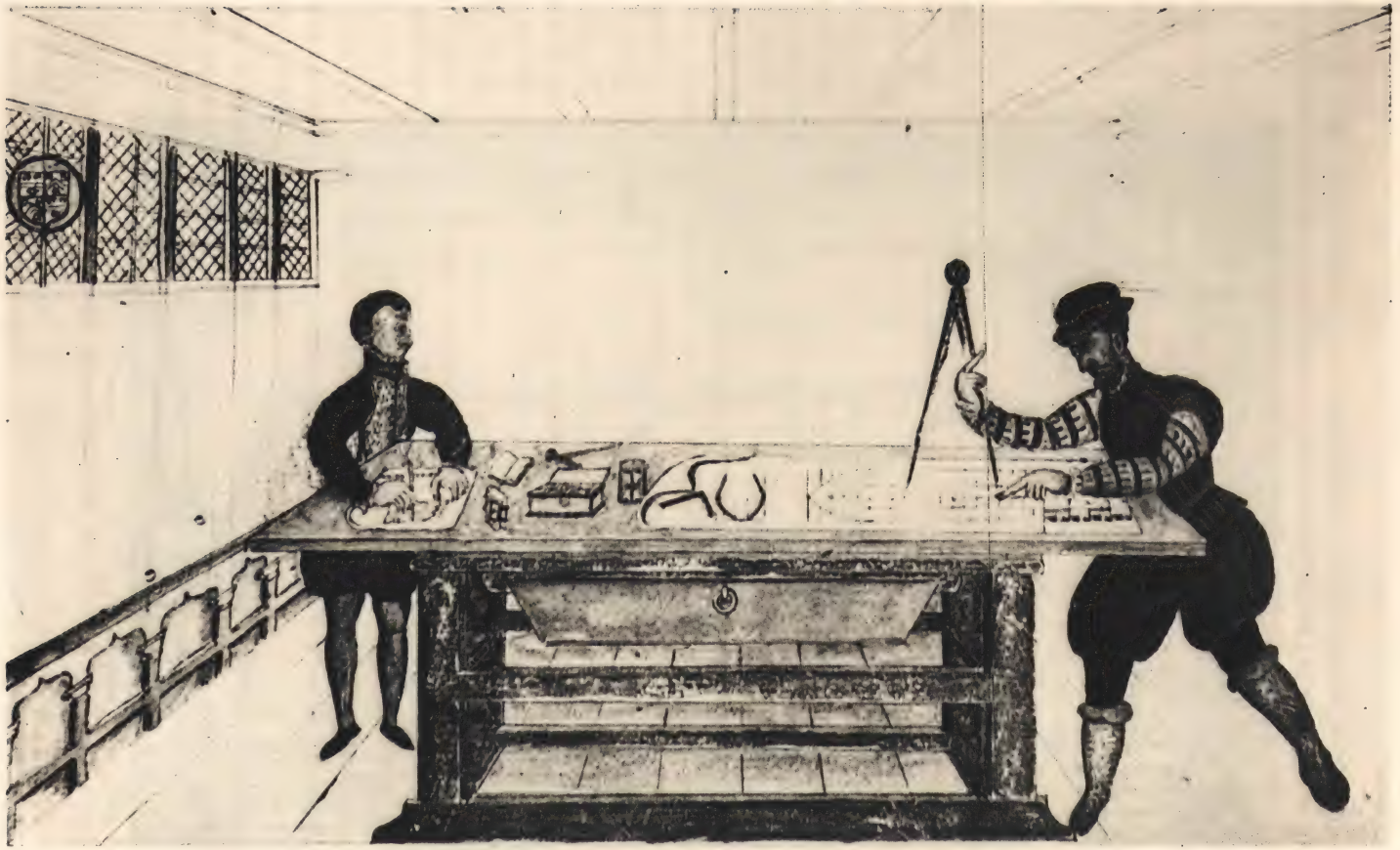
In 1629, the *Architecture Navalis* of Joseph Furttenbach published at Ulm, described Italian practice in the design of galleys, miscellaneous small craft, and large sailing ships. Much of this material is similar to that in the Venetian manuscripts previously mentioned. George Fournier's *Hydrographie* published in France in 1643 covering many marine subjects gives methods of drawing ships lines and for proportioning various parts. The first printed book in English dealing solely with naval architecture was Edward Bushnell's *The Compleat Shipwright* which appeared around 1665. It covers in some detail the design of a vessel of 60-foot keel length giving a sheer plan and a midsection outline.

One of the latest works of use in this study is Sir Anthony Deane's 'Doc-

[4] R. C. Anderson, 'Italian Naval Architecture about 1445,' *The Mariner's Mirror,* XI (1925), 135-163.

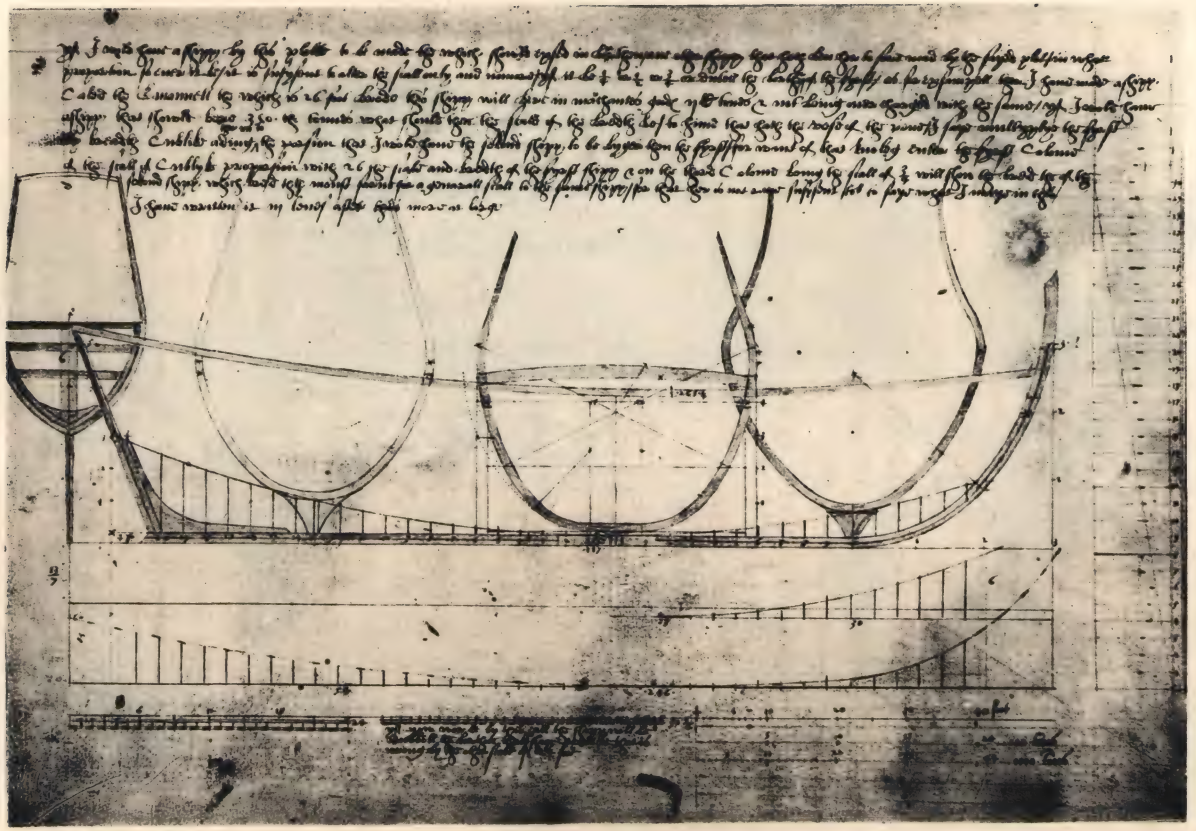
[5] Frederic Chapin Lane, 'Venetian Naval Architecture about 1550,' *The Mariner's Mirror,* XX (1934), 24-29.

[6] Vernon D. Tate, 'The Instrvcion Nauthica of 1587,' THE AMERICAN NEPTUNE, I (1941), 191-195.



Elizabethan shipwrights drafting a new ship

From Pepys 2820, Magdalene College Library



Profile and sections of Elizabethan ship

From Pepys 2820, Magdalene College Library

trine of Naval Architecture,' a manuscript prepared in 1670 at the request of Pepys.[7] Deane, who lived from 1638 to 1721, served the Royal Navy as a master shipwright and a commissioner in charge of various yards and enjoyed a high professional reputation. His manuscript gives a series of plans for six different 'rates' of ships, data on items of equipment, rigging, victualing, and manning, and describes a method of drawing ships' lines.

Falling roughly in the middle of the survey range and of the utmost value to this study are the two English manuscripts mentioned in the previous discussion of the dimensions of *Mayflower*. The first of these, 'A Most Excellent Mannor for the Building of Shippes,'[8] an anonymous work of about 1600, gives several outline drawings of midsections differentiating between 'men of warr' and 'marchauntt men.' The second, from which the basic data for the form of the proposed replica was taken, was preserved by Pepys and was titled by him 'Fragments of Ancient English Shipwrightry.'[9] It is attributed to Mathew Baker, one of the master shipwrights of Queen Elizabeth I, and has been dated *circa* 1586 by English authorities. From a study of this manuscript the writer believes it to be of the notebook variety compiled over a period of time. The original author did not use all the pages for data pertaining to ships for there is much mathematical material in another hand dated 1615.

While the 'Fragments of Ancient English Shipwrightry' is written in English the spelling and letter forms are such as to make its reading something like an exercise in cryptography. Much of the information it contains is incomplete in many respects but some details can be clarified by reference to Deane's work. There are references to the Greeks and Venetians and one authority believes that the well-known profile of a large four-masted ship of the period represents a Mediterranean vessel rather than an English one. Yet notes on certain diagrams show that they were used in designing some of the Queen's ships, particularly *Foresight,* 1570, and *Vanguard,* 1586, hence it is a reasonable source of design data for the proposed replica.

Ships of the early seventeenth century, indeed long before and for

[7] The full title is 'Anthony Deane's Doctrine of Naval Architecture and Tables of Dimensions, Materials, Furniture and Equipment appertaining thereto. Written in the Yeare 1670 at the Instance of Samuel Pepys, Esq.,' Pepysian Library No. 2910. Some of Deane's instructions are published in Sir Westcott Abell, *The Shipwright's Trade* (Cambridge, At the University Press, 1948).

[8] Anonymous MS., 'A Most Excellent Mannor for the Building of Shippes,' Scott Collection, Institution of Naval Architects, London. By courtesy of the Institution of Naval Architects. Hereinafter referred to as the I.N.A. MS.

[9] Mathew Baker's Notebook, Pepys 2820, Magdalene College Library. Plates 31 and 32 are also from this work. By courtesy of the Master and Fellows of Magdalene College, Cambridge.

long after, had definite shape characteristics quite apart from the decorative features so apparent in old prints. The upper works were most noticeable as they tumbled home to high, narrow decks, that is, the sides sloped or curved inward from the waterline. The upper decks which carried guns were kept narrow for several reasons. The weight and recoil of the guns put a severe strain on the structure and it was difficult to obtain long beams of suitable size; joints in beams were a source of weakness.

Of great importance in the design was the shape of the largest section and its location in respect to the length of the vessel. The widest part of this section was just above the load waterline to keep the ship from heeling too far under the wind pressure on the sails. This breadth was raised towards the ends to improve seaworthiness in heavy weather by providing extra buoyancy and to give fine sections below for easy passage through the water.

The largest section was located somewhat forward of the midlength of the vessel to give a full bow and a fine stern. One drawing in the Baker MS. showing the profile of a fish drawn on the underbody of a ship is an early example of the long-held theory that a good ship should have 'a cod's head and a mackerel's tail.'

An attempt to describe ship design procedure of the sixteenth and seventeenth centuries in any space less than a full-fledged textbook would be foolhardy to say the least. And to all except the technically minded such a description would be boring. But by reference to Plate 32, a drawing from the Baker MS., and Figure 4, the lines for the proposed replica, some interesting details can be noted.

Briefly, the process of hull design consisted of setting down on paper a profile showing the keel, stem, and sternpost, the outline of the maximum section, a maximum breadth line in plan and profile, and the breadth and rise of floor lines. The curved lines are true arcs of circles, combinations of arcs, or lines derived from circles. Using the above basic lines as guides, the transverse sections through the ship were drawn in with a compass and straightedge. Available data indicates that these were transferred directly to the timbers, the shipwrights having no knowledge of fairing the sections by means of waterlines and buttocks.

The first step is to set out the length of the keel and to draw in the stem and sternpost. The overhangs of the stem and sternpost were termed the 'rakes' and, while there does not seem to be any specific data for the amount of rake at each end, the sum of the two usually equalled the maximum breadth. Published data indicates that in actual ships the

forward rake was often greater and the stern rake less than shown on the drawings in the Baker MS. Plate 32 shows a stem profile composed of two arcs tangent to each other on a diagonal with the lower arc tangent to the keel. Other drawings show but one arc with a definite knuckle at the junction with the keel. The profile of the replica has a keel length of fifty-eight feet and uses the two-arc type of stem. The stern rake is greater than would be indicated by the published data for similar sized vessels but not as great as the drawings in the Baker MS.

The next step is to delineate the maximum section, usually termed the midship section although it is not always located at the midlength, and in this there is a considerable choice of method. The available examples generally follow that shown in Plate 32 which on each side of the centerline is composed of four arcs of circles and two straight lines—in a few the upper portion is a reverse curve rather than a straight line. The Baker MS. notes that a four-arc section with straight lines is in the Venetian manner. A section having a curved floor, noted as the Greek method, and another flat-floored section marked as Lyntton's system are also shown. The I.N.A. MS. gives detailed dimensions for both curved-floor and flat-floored sections. This curved-floor detail, coupled with the fact that this MS. contains rules for the proportions of galleys, suggests that it may be an English translation of a Mediterranean shipbuilder's notebook.

The best described section in either MS. is a three-arc and straight-line section given in the Baker MS. One of the design problems for the replica was the determination of a reasonable method for the progressive reduction of the various radii from the maximum section to the ends. By choosing this type of section there were a minimum number of arcs to worry about. Figure 1 shows the outline of the midship section for the proposed replica. Mathew Baker starts his description 'Fyrst ther moste be maed with the bredth and depth of the shipp a paralillogram whose half shall souffyes for this works' but it is better to continue the description in modern English and the dimensions of the replica.

In Figure 1 the basic rectangle made with the breadth of 25 feet and the depth of 12 feet 6 inches is ABDC and the half 'that shall suffice' is CDEF. One-fifth of the half breadth ED—2 feet 6 inches—is subtracted from the depth CD thus locating point G—the line HG is drawn parallel to ED. A line drawn from E to C intersects HG at point J and a perpendicular KM is erected from the base line through this point. The half breadth of the floor is then EK and as the depth of the vessel is equal to half the breadth, half the floor is the same as DG or 2 feet 6 inches.

The distance HL is set out as two-thirds of ED. Now with a compass the center N is found on KM so that an arc tangent to the base line at K will pass through L. The second center O is found in the same manner on the projection of the line LN while the third center is at Q, found by projecting a line from P through N. Point R is the same distance above

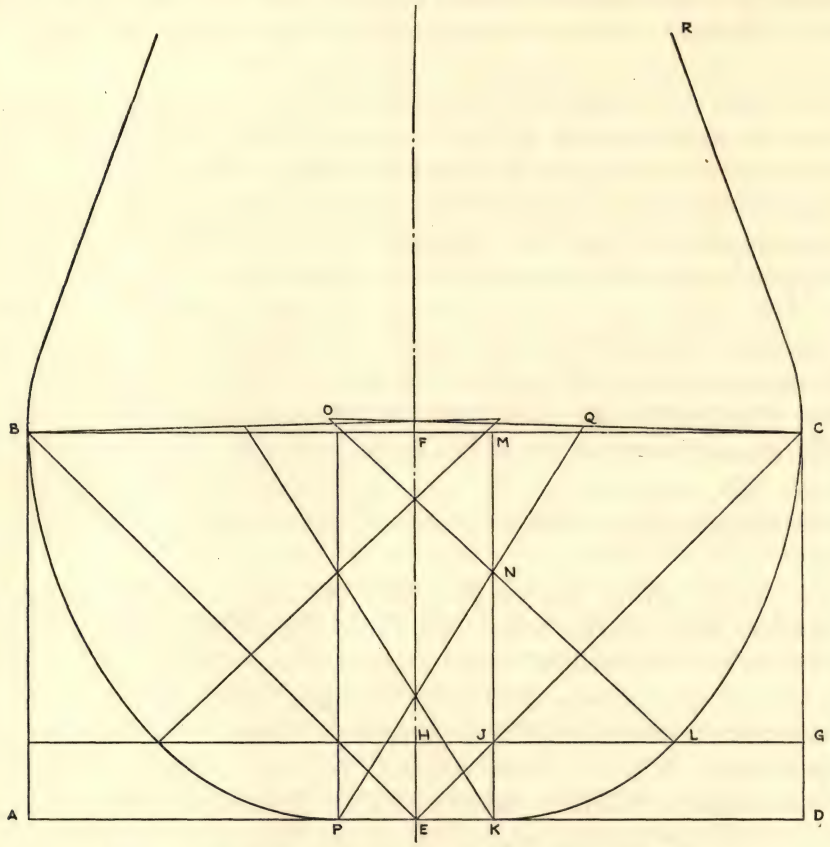


Fig. 1. Outline of Midsection for *Mayflower* Replica.

Q that Q is above the base line AD. The total breadth at R is two-thirds of the breadth of the ship AD.

In the earlier discussion of dimensions for the proposed replica one of the reasons for the rejection of the dimensions and proportions of *Adventure* of Ipswich as a basis was a comment on the tonnage rule of 1582 by the masters of Trinity House: 'The old rule is less true for lately built ships, which have great floors, but true for old ships with small floors.' The floor is defined in an old dictionary of about 1620 as 'so much

of the bottom of her as she doth rest upon when she is aground.'[10] The widths of floor have been measured on ten of the sections shown in the Baker MS. and these range from one-sixth to one-third of the maximum breadths; that shown on Plate 32 is about three-sixteenths. Two sections in the I.N.A. MS. have breadths of floors equal to three-tenths and four-tenths of the maximum. In 1670, Deane set out the breadth of floor as one-third of the breadth of the ship. The above instructions for delineating the midship section result in a floor breadth of but two-tenths of the maximum breadth. In view of this, the tonnage rule of 1582 that was used in the derivation of the dimensions of the replica is particularly applicable considering the Trinity House comment above.

As for the proper location of the maximum section on the keel, Mathew Baker gives the rule used by the 'Ciscilianes and Candians' but modifies this in the light of his own experience. Without getting bogged down with details and involved explanations, the rule as modified gives a location equal to 0.362 of the keel length abaft the forward end of the keel —for the replica this is 27 feet. This percentage is used on three of six profiles in the Baker MS., the remaining three are 0.308, 0.368, and 0.388 showing that he was not set in his ways.

In 1666 Samuel Pepys stated that Sir Anthony Deane was the first to be able to foretell the draft of a ship before it was launched. Mathew Baker was part way along the path to this knowledge as he discusses the effect of the location of the midship section on the trim of the vessel, trim being the difference in draft between the bow and the stern. He stated 'yf the same senter hade ben set on the myedest of the kell then the shipp wold have draw ase much water afore at the forefoot as abaft at the tuke. now foreasmuch as the sentur is moved forod . . . the shipp will hange astarne as all shipp doth hose flower lyeth before the mydest of the kell. nowe to know what this shipp will draw abaft more then afore, worke by the ruell of proportion. . . .' This 'ruell of proportion' relates the position of the midship section to the height of the 'tuke,' i.e. tuck, the junction of the flat stern with the sternpost. Working this out for the replica indicates that she would trim twenty-three inches by the stern.

For the drawing of the profile, the shape of the midsection, and locating the position of this section, there have been definite instructions or good drawings plus definite dimensions. For much of the remainder of the work in drawing the lines, the design procedure is less clear. To shape the bottom of the ship the breadth of floor, EK in Figure 1, and

[10] G. E. Manwaring and W. G. Perrin, *The Life and Works of Sir Henry Mainwaring* (London, The Navy Records Society, 1922), II, 149.

the lowest radius, KN, must be progressively reduced at each section towards the ends of the vessel and at the same time, the floor line must rise. Similarly, the body of the ship is shaped by suitable variations of the remaining arcs and their centers. The lines that guide these progressive variations for shaping the floor and body of the vessel are termed the rising and narrowing lines. Plate 32 shows only the rising line for the floor and the narrowing line for the body but, fortunately, the three sections shown in addition to the midship section make it possible to develop the narrowing of the floor and the rising of the body.

From the midship section aft it can be seen that the breadth of floor has been reduced to zero at roughly half the distance to the stern but that the lowest radius has been kept the same to that point. From there to the stern this radius is also reduced to zero. Working forward from the midship section, the breadth of floor becomes zero at the forward end of the keel while the radius is held as in working aft. The above pattern was followed in shaping the floor of the replica and, in the absence of definite information, it was assumed that the radius forward would be reduced to zero where the rising line intersects the stem.

By 1670 when Deane prepared his 'Doctrine of Naval Architecture' of Pepys, the tapering of the breadth of floor was carried out over the entire length of the vessel instead of to the intermediate points described above. There are indications in the Baker MS. that this was proposed if not actually done in some instances before 1600.

An indication of the rising line for the maximum breadth can be obtained by plotting the heights of the maximum breadth on each of the four sections shown on Plate 32. In keeping with the general method of design this should be an arc of a circle. Based on the measurements from Plate 32 it was so drawn for the replica.

The narrowing line that determines the maximum breadth at each section is clearly shown in Plate 32 as a combination of two arcs. There is a long radius arc from the stern to about the forward end of the keel and a shorter radius arc shaping the bow. Similar narrowing lines are indicated on other drawings in the Baker MS., a few being somewhat bluffer in the bow. By use of one of the diagrams in the MS. the sections toward the stern may be made somewhat wider than a true arc would indicate. This particular diagram has been cited as the basis for dating the Baker MS. as *circa* 1586 for it has the note 'The firste that wase mad by this wase the *Vanguard.*' She was a large vessel of 449 tons burden built by Mathew Baker in 1586. In keeping with the premise that the replica

should represent a burdensome carrier the bluffest of the bow lines in the Baker MS. and the above noted diagram were used in drawing the breadth narrowing line for the replica.

While the shape of the rising and narrowing lines of the floor have a considerable effect on the shape of the ship, those for the breadth have even more, particularly at the bow. The high rising line forward, as derived from Plate 32 and used in developing the lines for the replica, produces relatively fine lines in the forebody. The armament of warships was greatly increased during the sixteenth century particularly in the ends of the vessels. Since the fastenings of the ship's structure were relatively poor, the whole fabric was quite elastic and this additional weight in the ends caused them to droop, a condition termed 'hogging.' Shipbuilders had to struggle with this hogging tendency until the end of the days of the large wooden ship. In the late sixteenth century it was partially overcome by increasing the displacement at the ends of the vessels.

To increase the displacement aft, the narrowing line for the breadth was pushed out but the rising line was held in about the same position as on Elizabethan ships. Forward, the breadth was increased and the bow arc made bluffer but the important change was the lowering of the rising line to a position nearer the load waterline of the ship. This position is shown very clearly on one of the plans in Deane's MS. It is a mistake to use this type of bow on an early sixteenth-century vessel.

In Plate 32 the curved shaded band running the length of the profile, like many of the other lines an arc of a circle of large radius, affects the external appearance of the ship rather than its shape. It represents one of the heavy timbers called 'wales' which serve to strengthen the vessel and to give the apparent sheer line. Many old prints and paintings show decks following the sheer of the wales—a common error, but one wonders how an artist expected sailors to stand on such decks. Actually there was little relation between the interior deck lines and the exterior appearance of an Elizabethan ship.

With the rising and narrowing lines for the floor and for the maximum breadth at each section determined, all the sections forward and aft of the midship section can be drawn in by progressive changes of the three arcs or 'sweeps' used in delineating the midship section. Two problems remain, the first being the reverse curve from the floor down to the keel where the floor rises towards the ends of the vessel. It is obvious from Plate 32 that in working aft from the midship section, this reverse curve reduces to zero at the stern. In working forward, the reverse at the quar-

ter length is shown but the ending is unknown. Again recourse was made to Deane's work and some reasonable looking sections were derived for the replica.

The second problem is the determination of the shape of the upper works which again were settled by reference to Plate 32 with some guesswork at the forward end. The sections aft are all straight lines with progressively decreasing slopes from the midship section to the stern. Forward, the slope of the midship section was gradually worked into a reverse curve. Thus, the body plan for the proposed replica as shown in the center of Figure 4 was drawn. As a check on the sections and to make the lines more intelligible to the eye of a modern naval architect, the waterlines and buttocks were drawn.

There are, unfortunately, very few published sets of lines representing sixteenth- and seventeenth-century vessels with which to compare those drawn for the proposed replica. Such lines as are shown in early printed works on shipbuilding are usually for the larger types of warships and generally are incomplete. Those in old manuscripts are usually about the same although Deane does show one complete design, the earliest complete scale drawing of a ship known in England. The dimensions of this design are close to those of *Rupert* built in 1666 which brought Deane much fame as a builder—length 120 feet, breadth 36 feet, and depth 14 feet. Plans published in historical surveys such as Charnock's *History of Marine Architecture* must be considered carefully as in this particular example, plates purporting to show vessels of the sixteenth century were engraved about 1800 using the then current methods of design.

Old models from which the lines have been lifted again are usually of warships; rarely were models made of the ordinary small merchantmen. Votive models for hanging in churches were often distorted, particularly in depth, to give a better appearance when viewed from below, but the so-called Admiralty type built-up models are generally considered to be fairly accurate. However, it is felt that in lifting and redrawing the lines from any type of old model, many of the characteristic bumps would be smoothed out by modern draftsmen.

As for modern models or drawings of ships of the period, the majority have but few of the characteristics shown by the Baker MS., the I.N.A. MS., or even by Deane's work. Those published by Professor F. Alexander Magoun are definitely of the 'round chunky variety.'[11] Plans labelled *Mayflower* that are offered by a firm specializing in model supplies are

[11] F. Alexander Magoun, *The Frigate Constitution and Other Historic Ships* (Salem: Marine Research Society, 1928).

for a ship of at least one hundred years later. The lines for Dr. R. C. Anderson's model, now on display in Pilgrim Hall, Plymouth, Massachusetts, do not seem to have been published although the outboard profile and sail plan did appear in the *Mariner's Mirror*.[12]

Perhaps the best for comparison with the proposed lines are those for a model of a large four-masted Elizabethan warship and a set drawn in accordance with Deane's instructions to illustrate a technical paper on ship forms. Of course, there is Deane's original plan but the lower reverse curves in the forebody have been drawn in so roughly that they are unreliable for checking the shapes of the lower waterlines.

The model of the four-masted Elizabethan warship was designed and built in the Science Museum, London, about 1931 and is based largely on material in the Baker MS. A description of this model, reproductions of certain pages from the Baker MS. and the lines plan were published in the April 1932 issue of *Yachting*.[13] The dimensions are those of *Elizabeth Jonas* as rebuilt in 1596—length of keel 100 feet, breadth 36 feet, and depth 18 feet. The profile and waterlines of this design are shown in Figure 2.[14] To be noticed in particular is the local bump forward on the lowest waterline similar to those occurring on the 2-foot and 4-foot waterlines of the proposed lines.

The lines to Deane's rules shown in Figure 3 were drawn by Dr. G. S. Baker, O.B.E., to illustrated his paper on 'Development of Hull Form of Merchant Vessels' in 1937;[15] the dimensions are the same as Deane's. Three points derived from a breadth narrowing line in the Baker MS. were plotted to show how the breadth was increased during the sixteenth century. A low waterline was plotted on this drawing and it shows the same local bump forward as noted above for *Elizabeth Jonas* and the proposed lines.

Considering the drafting methods employed, the proposed lines as a whole are surprisingly good and indicate that a vessel built to them should be reasonably fast. *Mayflower*'s return voyage to England of thirty-one days is proof that she was no slouch.[16] The poor windward sailing abilities of ships of the period can be attributed more to the sails and rigging than to hull form. If modern methods had been used in drafting

12 R. C. Anderson, 'A "Mayflower" Model,' *The Mariner's Mirror*, XXVI (1936), 260-263.

13 Weston Martyr, 'Looking at a Sixteenth Century Ship,' *Yachting*, April 1932, p. 61-63, 110.

14 Reproduced by permission of Yachting Publishing Corp.

15 G. S. Baker, 'Development of Hull Forms of Merchant Vessels,' The Sixth Andrew Laing Lecture, North East Coast Institution of Engineers and Shipbuilders, Newcastle-upon-Tyne, England, December 1937. Lines reproduced by permission of the N.E.C. Institution from *Transactions*, LIV, Part 2, 58-59.

16 Magoun, op. cit., p. 43.

the lines, some of the sharp reverses in the waterlines and the local bumps would have been smoothed out but many characteristics of early sixteenth-century ships would have been lost. The lines shown in Figure 4 are the fourth set drawn for the proposed replica and it is believed that they are as typical of the period as reasonable study and effort can produce at this time.

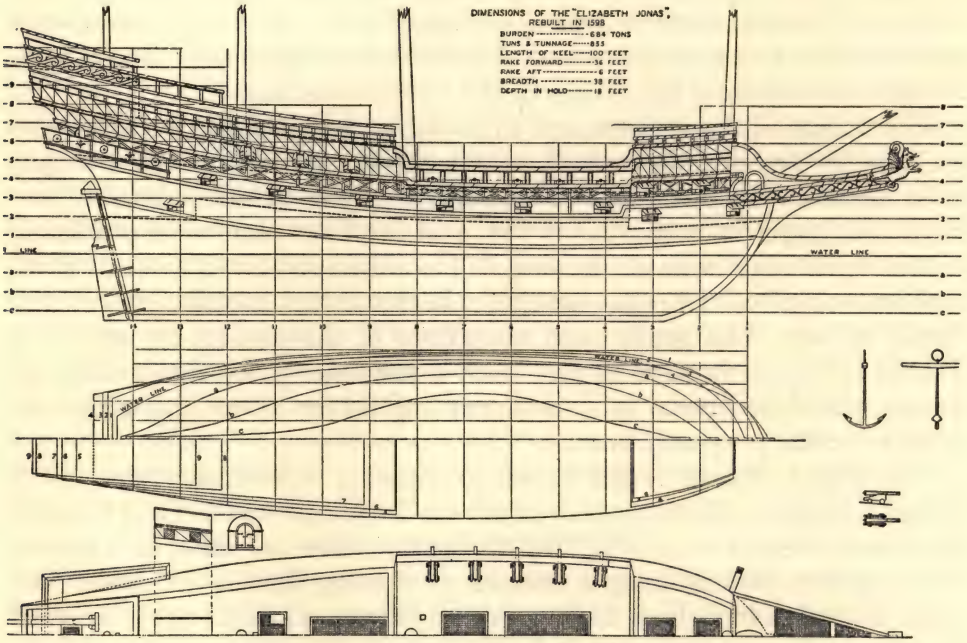

DIMENSIONS OF THE "ELIZABETH JONAS",
REBUILT IN 1598
BURDEN ---------- 684 TONS
TUNS & TUNNAGE ---- 855
LENGTH OF KEEL ---- 100 FEET
RAKE FORWARD ------ 36 FEET
RAKE AFT ---------- 6 FEET
BREADTH ----------- 38 FEET
DEPTH IN HOLD ------ 18 FEET
WATER LINE

Fig. 2. Lines of large Elizabethan Galleon, *Elizabeth Jonas*.

APPENDIX

The so-called 'lines' of a ship is the plan that delineates the form of the vessel. It may look quite complicated to the uninitiated but, in reality, it is quite simple as it merely represents a ship cut by planes in three directions. The ship is shown in three views—the side view or profile, the end view or body plan, and the bottom or plan view.

Perhaps the simplest description of 'lines' may be to liken a ship to a loaf of bread—say a loaf of French bread well pointed at the ends. The outline of the loaf as seen from the side is its profile. Assuming this loaf of bread to have been purchased ready sliced, the cuts show only as vertical lines on the side or profile of the loaf. If, however, one looks at an end of the loaf and peels off slice after slice in succession, the change in shape from the pointed end to the largest slice is readily apparent. Similarly, the sections of a ship are vertical lines on the profile while

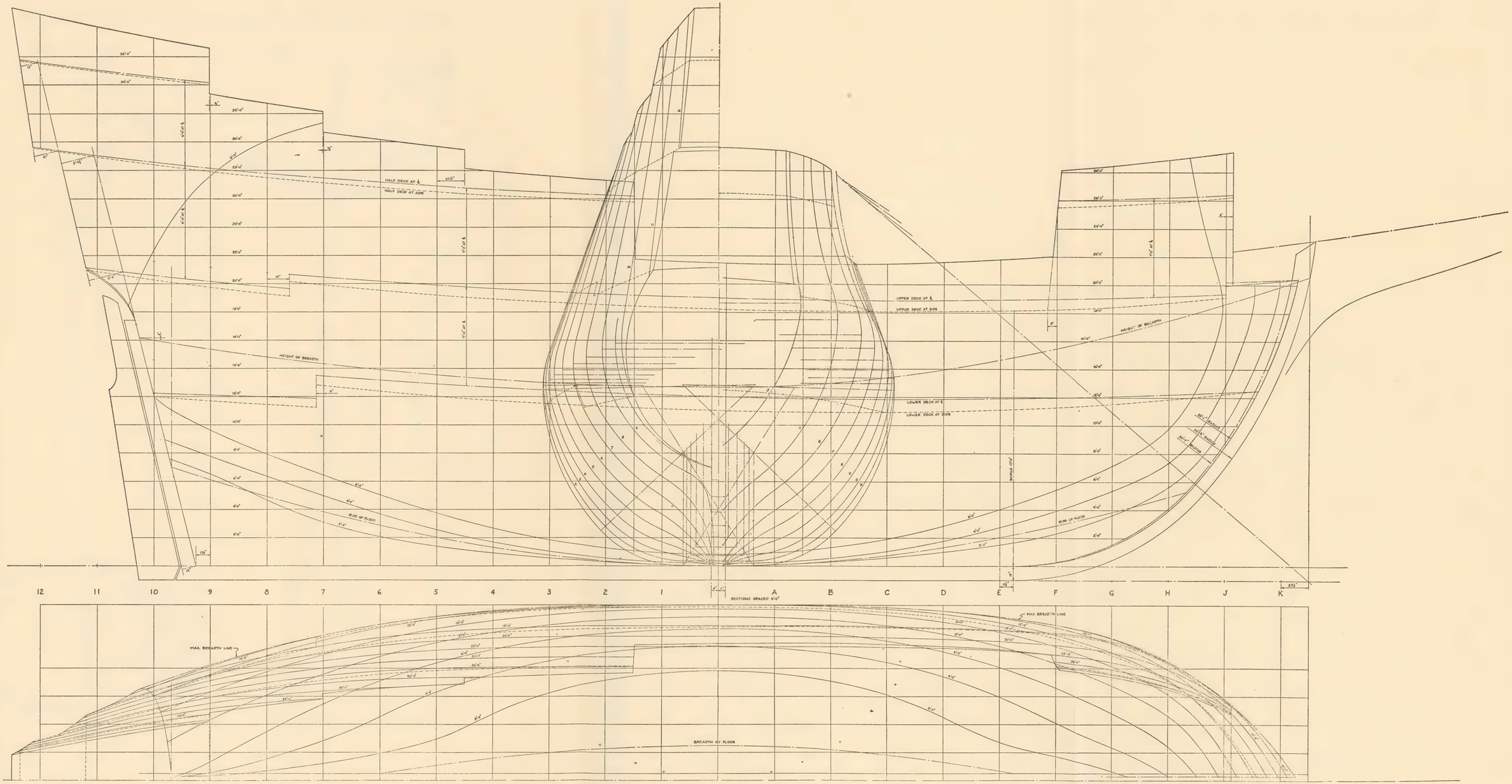

HALF DECK AT ℄
HALF DECK AT SIDE
UPPER DECK AT ℄
UPPER DECK AT SIDE
LOWER DECK AT ℄
LOWER DECK AT SIDE
HEIGHT OF BREADTH
RISE OF FLOOR
MAX. BREADTH LINE
BREADTH OF FLOOR
SECTIONS SPACED 4'-0"
12 11 10 9 8 7 6 5 4 3 2 1 A B C D E F G H J K

Fig. 4. Lines for *Mayflower* Replica.

Length of keel to back of main post—58 feet 0 inches, Breadth within the plank—25 feet 0 inches, Depth to the breadth—12 feet 6 inches, Burden by rule of 1582—181 tons

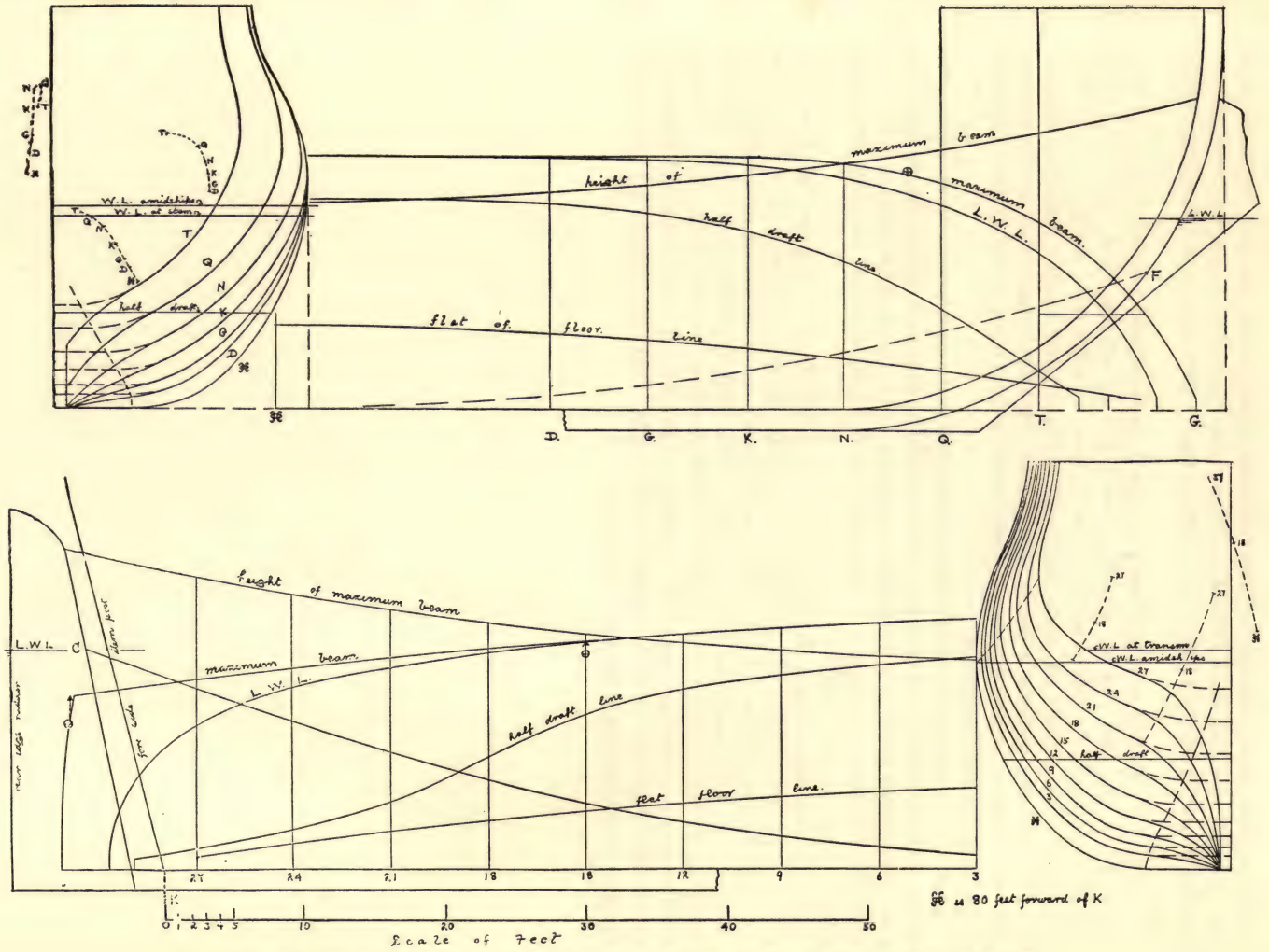


Fig. 3. Lines of Vessel of 1670. Based on Rules in Sir Anthony Deane's MS.

the body plan shows one half of these sections as seen from the end—from the bow on the right side and from the stern on the left. For convenience the body plan is usually drawn on the profile or side view using the maximum section as the centerline.

If, however, the loaf of bread was purchased unsliced and one has at hand a large sharp knife, the loaf can be sliced in two other directions. First, let it be cut in layers parallel to the bottom. These will show as horizontal lines in the profile but, as they are peeled off, each shows the characteristic double pointed shape of the loaf. On the ship such horizontal planes are called waterlines and represent different levels at which the ship may float. On a lines plan, the waterlines are usually drawn below the profile.

Instead of being cut parallel to the bottom, the loaf could have been sliced lengthwise parallel to the centerline. Such slices would appear as straight lines in both the end and bottom views but would have shapes similar to the profile when seen from the side. On the ship these are commonly called buttocks and are long sweeping curves drawn on the profile.

In modern ship design the waterlines and buttocks are long sweeping smooth curves, parabolic rather than circular in nature. When drawing a set of lines, the naval architect takes particular care that there are no local bumps or hollows, that all lines are 'fair' and that intersections of the sections, waterlines, and buttocks check in all three views. The Elizabethan shipwright, working with arcs of circles for the sections and having no knowledge of the use of waterlines and buttocks, produced ships' lines that were quite 'unfair' since where arcs of various radii come tangent, a definite local bump can be seen.

THE ARRANGEMENT AND CONSTRUCTION OF EARLY SEVENTEENTH-CENTURY SHIPS

By

WILLIAM A. BAKER

PLYMOUTH
Plimoth Plantation, Inc.
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Reprinted from *The American Neptune*

Vol. XV, No. 4, 1955

Printed by The Anthoensen Press, Portland, Maine

The Arrangement and Construction of Early Seventeenth-Century Ships

BY WILLIAM A. BAKER

THE characteristics of a sailing ship of an earlier day can be presented to the public in three different ways; the effectiveness of the result depends largely on the medium chosen. The simplest method of depicting such a ship is two-dimensional, that is, by means of a drawing or painting. It is obvious that while many details can be shown, much is hidden or can only be suggested. For example, unless the viewpoint chosen is unusual nothing can be shown of the deck arrangements and it is difficult to give an idea of hull shape. On the other hand, the sails and rigging can be shown with considerable accuracy. In the main, however, an artist is concerned with creating a feeling of the ship and in showing the items that readily meet the eye—the sweep of the sheer line and the rails, the details of decoration, the set of the sails, the condition of the sea, and the play of light on all.

A more satisfactory way of presenting the characteristics of a ship, from the technical point of view at least, is three-dimensional, by means of a model. With a model, the shape of the hull, both the under- and above-water portions, can be shown as well as the arrangements of the weather decks, the miscellaneous fittings, and all the spars and rigging in detail. Sails are usually but clumsy additions and are out of place unless the model be large enough to have the cloth of which they are made of the proper scale thickness. While models may seem somewhat lifeless compared to many drawings and paintings, they do give a feeling of form and mass that cannot be had from two-dimensional portrayals. A series of models built to one scale can be very useful in showing changes over a period of time.

Neither an artist's conception of a ship in black-and-white or color nor a model can convey adequately the impression of the mass of an actual ship, of the sizes of equipment, and of the space available for living and working. Omitting from consideration specially constructed school ships,

there are relatively few vessels of by-gone days still in existence in complete enough form to give those interested more than an impression of their shape, construction, rigging, and how people lived and worked aboard. The oldest of such vessels now preserved are the three viking ships that are exhibited under cover at Oslo, Norway. England has preserved Nelson's flagship at Trafalgar, the 100-gun ship-of-the-line *Victory,* and the tea clipper *Cutty Sark,* both of which are now in dry berths.

In this country the last of the wooden clippers was burned for her metal some thirty years ago and the great coasting schooners have gone but for a few rotting in the backwaters. The majority of the remnants of the once great fleet of small coasters are in the summer tourist trade where they are able to give some impression of life in sailing vessels. For large vessels we do have a rebuilt frigate of 1797, U.S.S. *Constitution,* the old whaler *Charles W. Morgan,* and two foreign-built iron square-riggers of the late nineteenth century. For smaller vessels, there is the rebuilt brig *Niagara,* several schooners including one poor example of the famous Gloucester type, and a couple of Revolutionary War gondolas that have been raised from the bottom of Lake Champlain. In addition to the above, there are a few old naval vessels whose present condition cannot be considered as one of preservation.

To remedy this lack of vessels, particularly of those associated with historic events, replicas have from time to time been constructed. These replicas range from full-sized vessels whose design is based on the best information available at the time of construction to small-scale ones that usually give no more than an impression of a ship. The former are generally built to be displayed at some large exposition while the latter are more often associated with pageants. The lives of replicas are usually beset with troubles. Interest in them runs high at the time of the event for which they are built but soon neglect and vandalism take their toll.[1]

Occasionally, replicas have been constructed as permanent educational exhibits, an excellent example being the one-half-size replica of the whaling bark *Lagoda* in New Bedford, Massachusetts. The proposed full-scale *Mayflower* replica to be built by Plimoth Plantation, Inc., of Plymouth, Massachusetts, will be one of this type. Some of the problems encountered in the selection of dimensions for this replica and in the delineation of its form have been noted previously in 'The *Mayflower* Problem' and 'Early Seventeenth-Century Ship Design.'

In general, neither the artist nor the model maker has to worry too

1 Alexander Crosby Brown, 'Some Replicas of Historic Ships,' THE AMERICAN NEPTUNE, XIV (1954), 105-114.

much about the structure of the vessels they depict or its effect on the location of fittings and the appearance of the vessels; structure can be adjusted to suit conditions but not ignored as is so often the case. Neither do they have to worry how various items of equipment were constructed or whether they would work properly as long as they appeared right. Many do not stop to consider whether seamen could live in and work the vessels that they show. For a replica, all such things do have to be considered, some of them in light of the availability of materials; for example, the cost of duplicating some of the timber sizes used on early ships would be almost prohibitive. In addition, for the *Mayflower* replica, problems connected with showing a considerable number of visitors per day through it had to be studied as they would have an effect on the final arrangement.

Little definite material is available on the arrangement and construction of ships of the early seventeenth century. While a few old technical books and manuscripts show some midsections, stem and sternpost details, and profiles with indications of decks, the majority of the information must be pieced out from written descriptions in conjunction with old prints and paintings. In studying old prints and paintings, one is faced with the problem of trying to judge how accurately the artist set down what he saw. Some of the results are obviously impossible even allowing for the known unusual features of early ships. Contradictions are also found when comparing the works of several artists. A further complication is the age of a vessel at the time it was portrayed. For a named vessel depicted during its lifetime there is no real problem, but for general types, a painting dated say 1610 may be showing a new ship or perhaps one twenty years old depending on what was in the harbor at the time the artist was working.

An ideal solution would be to go back in a time machine to view a large fleet and compare the characteristics of the various types. Fortunately, in a way, this is possible, for several northern European artists painted or engraved panoramic views of some of the ports which show many vessels of all types. While some of these are purely local craft—small coasters, fishing vessels, lighters, and the like—there are a considerable number of larger seagoing ships. In addition to the age problem noted above there is sometimes the complication of plagiarism. A view of Amsterdam engraved by Temini about 1620 has exactly the same vessels in the foreground as a similar view by another artist made about twenty years earlier. It seems reasonable at this late date to assume that twenty-five years is about as close as one can come to pinning down details; for some items even this may be too close.

Considering the seagoing vessels in such views, the majority have certain obvious features, apparent at even a casual glance, regardless of size. At the bow is a beak or ram-like structure protruding from the stem. The hull proper has a short superstructure forward, a low section amidships, and a long, relatively high superstructure from the mainmast aft. Practically all these vessels are armed, there being two or more gun ports on a side in all but the smallest ships.

From a study of the available material there is little doubt but that vessels of the assumed size of *Mayflower* had two decks in the main hull—the lower or gun deck on which the main armament was carried and under which the majority of the cargo was stowed and an upper deck which was the weather deck amidships. However, it should not be assumed that these two decks ran continuously from bow to stern as in later ships. The seven-

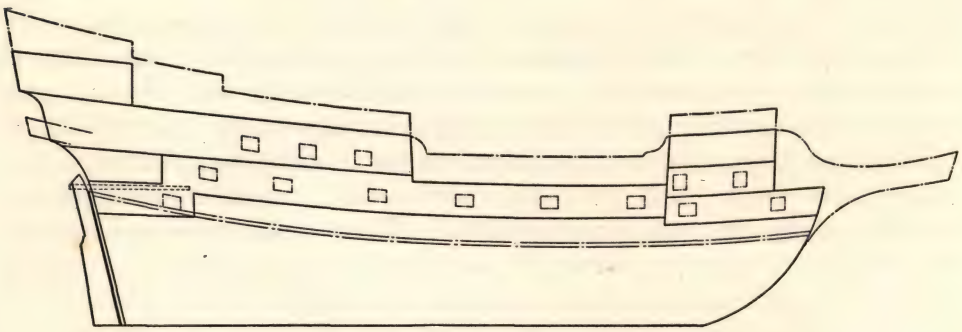

Fig. 1. Arrangement of decks—sixteenth-century galleon.
(After model—Science Museum, London.)

teenth-century shipbuilder had no such tradition to hamper his arrangement of a ship and he set his deck levels as needed to suit space requirements for cargo, stores or crew. A typical arrangement of decks in a large ship of the period is shown in Figure 1.

The short superstructure forward covering the upper deck is, of course, the forecastle, the lineal descendant of the old fighting platform. Similarly, the longer superstructure aft is a development of the 'after-castle' or 'summer-castle' which served originally as a command post and as a shelter for important persons carried as passengers. Superstructures were used first on vessels in the Mediterranean region, appearing later on northern European ships at about the time of the Crusades. Then, as large numbers of northern ships bearing armies and pilgrims went to the Holy Land, there was a definite interchange of ideas on ship construction and equipment. The single-masted square rig of the northern viking-

ship type was adopted for some of the Mediterranean cargo ships while the northern shipbuilders picked up such features as windlasses and the superstructures.

The fore- and after-castles long remained little more than the light angular structures of the house carpenter superposed on the strong curved work of the shipwright. The earliest ones were light platforms supported on stanchions above the weather deck; when necessary the spaces below these platforms were enclosed with light sheathing. Such superstructures could easily be swept overboard in a severe storm and, as they grew in size, a better method of securing them to the hull was required. The system generally adopted was to fit heavy vertical tie timbers on the outside extending well down on to the main hull. Such vertical timbers remained a feature of decoration for a half century or so after the framing of the superstructures had become an extension of that of the main hull. This change of framing was accomplished during the first half of the sixteenth century.

By the early seventeenth century, the space within the forecastle was probably of more importance to the ship than the space on the forecastle deck which originally determined its worth as a fighting platform. Just how this forecastle space was equipped and used, or indeed, exactly how any of the smaller enclosed spaces were fitted out, is open to question. It is reasonable to assume, however, that one item in the forecastle of small merchant ships was the galley.

The usual 'cook-room' or galley on a large ship of the Elizabethan era was a solid structure of bricks and mortar built on gravel ballast in the hold. In spite of many recommendations, starting with those of Sir William Wynter in 1578, that the galley be moved to the forecastle, it long remained in the hold of warships, or at least on a lower deck, in some cases as late as the early eighteenth century. The hold location was objectionable for several reasons. The structure beneath the pile of bricks and mortar could not be examined; heat, smoke, and fumes permeated the ship affecting the health of the crew and spoiling stores. Further, there was always the danger of fire. On the other hand, from the military point of view, the forecastle position had its limitations. A lucky shot could easily put the galley out of commission and add flying bricks to the other projectiles. In merchant ships, however, the hold space could be used more profitably for the carriage of cargo, hence the forecastle location for the galley.[2]

[2] M. Oppenheim, *A History of the Administration of the Royal Navy and of Merchant Shipping in Relation to the Navy* (London and New York: John Lane, The Bodley Head, 1896), p. 128.

Before leaving the forward end of the ship, it might be well to describe the beak mentioned above. Most people having some knowledge of sailing ships are familiar with the so-called clipper bow—a clean concave profile with a simple figurehead. Many can trace its simplification from the relatively complicated structure that was fitted on such vessels as U.S.S. *Constitution*. Few, perhaps, realize that the clipper bow was the final development in a long line that started with the ram of ancient war galleys. The bow structures were originally termed 'beaks,' then 'beakheads,' and finally just 'heads.' A study of their complete development would easily fill a fair-sized book.

On sailing vessels, the forecastle, in its development from a simple platform, came to have a triangular plan form. The pointed forward end projected over the stemhead of the vessel while the after end was partially faired into the hull; the sides were generally vertical. These were substantial structures having, in some cases, two or more levels. Such forecastles were carried by the great carracks of the fifteenth and early sixteenth centuries.

The galleys of that period still depended on the ram as the primary weapon—this ram was a long solid projection of the main deck. One of the common ship types of the fifteenth and sixteenth centuries was the galleasse which was propelled by both oars and sails. There were many variations of the galleasse but in general the type had a more seaworthy hull and more sail power than the usual galley but less displacement than the normal sailing merchant vessel. It retained many of the galley features including the beak. Some of the galleasses of King Henry VIII of England had both a projecting forecastle and a beak.

Continuing with the development of ship types, one might expect from the name that the galleon, primarily a fighting vessel, would have oars, too, but it did not. The galleon type was merely influenced by the galley, being a little longer, a little narrower, and of lower build than the preceding sailing ships. The older projection of the forecastle over the stemhead was dropped to form a beakhead in imitation of the ram of the galley and galleasse. This left a square forward bulkhead on the forecastle in which, on large vessels, gun ports were usually cut for cannon to fire ahead. The early galleon beakheads had more or less vertical sides with solid planking, a carry-over from the solid sides of the projecting forecastles. The sides were highly decorated and there was usually a grotesque head or figure at the end. Often the upper profile was an S-curve terminating near the top of the forecastle. With the passing of time, the beakhead

became shorter, higher, and lighter in appearance, the planked sides giving way to open rails until the whole culminated in the bare clipper bow.

The beakhead on ships of *Mayflower*'s time served many purposes in addition to decoration. It broke the seas before they could damage the forecastle, provided a solid structure to which the bowsprit could be secured, and served as a place of convenience for the crew. The beakhead also served as identification. Those of English ships were described as being long and low while on Spanish and Venetian ships, for example, the steeve, or angle with the base line, of the beakheads was considerable.

While there is little question that there was but one level in the forecastles of ships of the size and type of *Mayfower,* the arrangement of the superstructure aft varied considerably. To give the space necessary for accommodations, two levels aft were common and there often were more. The size and height of the after superstructure were often carried to such extremes as to affect seriously the sea-keeping qualities of the ships. During the reign of Elizabeth I, many noted seafarers inveighed against excessive superstructures but their recommendations were usually not heeded by those responsible for having the ships built.

Sir Walter Raleigh stated, 'two decks and a half is sufficient to yield shelter and lodging for men and mariners and no more charging at all higher, but only one low cabbin for the master.' [3] The two decks noted are, of course, the upper and gun decks previously mentioned. The 'half' is the first level of supersctructure aft extending from about the mainmast to the stern and termed the 'half-deck' as it covered half the length of the vessel. Under this half deck at the very stern was the 'Great Cabin' and just forward of this was the helmsman's station, the 'steerage.' There was, naturally, a bulkhead at the forward end of the great cabin and some sort of a bulkhead at the forward end of the half deck. The latter, located just forward of or abaft the mainmast, may have been solid, particularly in large warships, may have had two or more arched openings or may have been not much more than small panels out at the ship's side. The second level aft was the poop deck, a short deck at the very stern that covered a single small cabin.

It is interesting to note that Raleigh mentioned men, mariners, and the master and these must be considered in the seventeenth-century sense when discussing the uses to which the various parts of the ship were put. Raleigh was presumably writing about the larger armed craft rather than the common merchant vessels and by the term 'men' referred to the fight-

[3] Sir Walter Raleigh, *Judicious and Select Essays and Observations* (London, 1650).

ing personnel in contrast to the mariners who operated the vessel. The captain of the vessel was the military commander and it was he who lived in the great cabin. The master was subordinate to the captain and was responsible for handling the ship; it was for him that Raleigh would provide 'one low cabbin.' On a small vessel such as *Mayflower* the duties of the military captain and the sailing master would have been combined in one person and on normal voyages he probably lived in the great cabin leaving the small cabin aloft for his chief mate. With the Pilgrims aboard his ship, it is reasonable to assume that Christopher Jones, master, turned the great cabin over to the leaders of the group while he moved into the small cabin aloft and sent the mate elsewhere.

The crew of *Mayflower* probably slept in hammocks slung in the 'tween-deck space or may have been content to curl up on a coil of rope. Not very comfortable perhaps but living conditions were crude in those days, even ashore. Early explorers of the New World found the natives using hammocks for sleeping and this useful article was introduced on ships of the Royal Navy in 1597.[4] How the 102 Pilgrims were crowded into *Mayflower* can only be imagined. It is recorded that the shallop freighted over in the 'tween-deck space 'was much opened, with the peoples lying in her.'[5]

Having settled on the probable number of decks in *Mayflower,* their vertical positions must now be determined. From midsections shown in Mathew Baker's notebook the levels of decks in relation to the height of the maximum breadth can be fixed, but two other points must be considered in laying out the heights at the ends.[6] The hawse holes forward are below the beakhead yet must be above the lower deck. Aft, the ports in the stern for the guns on the lower deck are below the main transom beam. A line connecting three points fixed with the above considerations in mind might be straight or even have a reverse curve similar to the popular sheer line for modern yachts. However, there is enough material available to show that the early seventeenth-century shipwright used a normal sheer line—low in the middle and high at the ends—and such a line requires steps in the lower deck at the ends to locate properly the hawse holes and stern ports. Reference has already been made to Figure 1 as showing the deck arrangement of a large ship. On smaller vessels, the

[4] M. Oppenheim, op. cit., p. 134.

[5] G. Mourt (William Bradford and Edward Winslow), *A Relation, or Journal, of the Beginnings and Proceedings of the English Plantation settled at Plimoth, in New England* (London, 1622).

[6] Mathew Baker's Notebook, Pepys 2820, Magdalene College Library. By courtesy of the Master and Fellows of Magdalene College, Cambridge.

forward step was often omitted leaving only the after step at the gun ports; this was done on the plans for the *Mayflower* replica.

One of the problems peculiar to a replica that must accommodate a large number of visitors arises in connection with fixing the heights of the upper and superstructure decks. Available evidence indicates that small ships had low deck heights and that these heights increased with the size of the ship. Scale drawings show that on some of the small ships the tops of the upper deck beams were located about 5 feet above those of the lower deck. On large ships, this dimension might be as much as 7 feet. From these figures must be deducted one thickness of deck planking and the depth of the beams under the upper deck, a total of about 12 inches, thus the above dimensions become 4 feet and 6 feet in the clear. A sea-

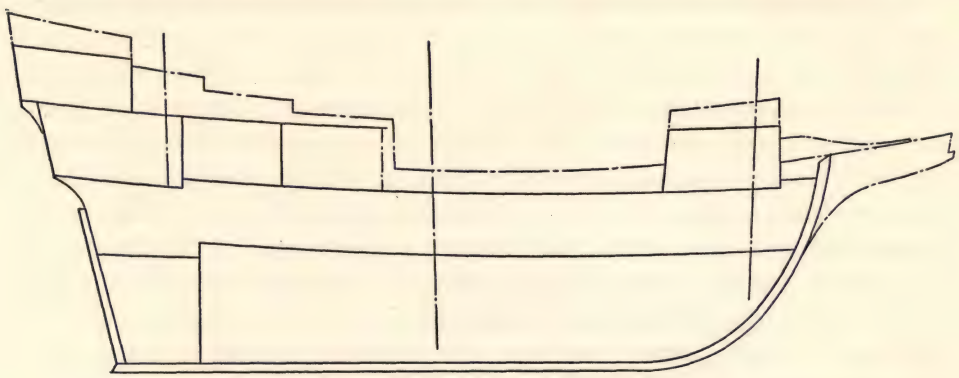

Fig. 2. Arrangement of decks—*Mayflower* replica.

man of the early seventeenth century could be expected to accustom himself to scrambling around in a restricted 'tween-deck space but not so with a present-day vistor, especially when it is known that man's average height has increased noticeably in the past three centuries. In consideration for the heads of modern-sized visitors, a molded dimension, i.e., from top of beam to top of beam, of 7 feet was chosen for most of the deck heights. This means that there will be about 6 feet in the clear through which the average visitor will be able to walk without difficulty. The small cabin aft will have a molded height of 6 feet—about 5 feet 3 inches clear—to show what conditions actually were like. Figure 2 is a simplified inboard profile showing the arrangement of decks as worked out for the *Mayflower* replica.

With the number and positions of the decks determined, some attention can now be given to the structure of ships of the early seventeenth

century. A study of old wrecks, manuscripts, books, and prints shows that this period was one of change in the method of framing ships. It might be argued that such a statement applies to any period as change indicates what is usually termed 'progress' or 'improvement.' Unfortunately, 'progress' or 'improvement' is not always desirable in the nautical field, as, for example, some types of vessels have been 'improved' out of existence. However, during the century from say 1550 to 1650, there does seem to have been a rather drastic change in the method of setting up a ship's frame. There are several reasons for this such as strength requirements occasioned by the increasing size of ships and the increase in armament, better protection against gunfire, and the growing difficulty in obtaining timber of the proper shapes.

To show this change properly a little of the history of ship construction must be outlined. Without going into the details of the development of ship framing it can be stated that by about A.D. 1100 there were in Europe two main systems of ship construction which may conveniently be termed the northern and southern. The northern system was that used in the north of Europe, particularly Scandinavia, and in England, while the southern was employed by the shipwrights of the Mediterranean region. In simple terms, the northern vessels had a light frame with lapped planking, now called the 'clinker' type, while the Mediterranean ships had a substantial frame with smooth planking, the so-called 'carvel' type. The well-known viking ships illustrate the northern system of construction but, unfortunately, there is no corresponding Mediterranean example.[7]

The two systems were arrived at from the methods used in fabricating a vessel's planking. The saw was a common tool in the Mediterranean region, it being shown in many old Egyptian tomb paintings. Hence, after felling a tree, the southern shipwright sawed it into planks and nailed them to the ship's frames. In the north, the saw was either unknown or uncommon and the adze and axe were the primary tools for converting a tree into planks. A log was split in half and a single plank was hewed from each half. In the hewing process, lugs were left at intervals on each plank. Holes were drilled in these lugs through which lashings were passed to secure the frames in place. The lapped seams of the northern vessels were fastened with iron rivets.

Another important difference between the two systems was the method of supporting the decks. The southern shipwright let the ends of the deck beams protrude through the planking and supported them on strongly

[7] A more detailed history of ships' structure may be found in a paper by the author entitled 'The Development of Wooden Ship Construction—a Brief Survey to the Nineteenth Century,' published by the New England Section of the Society of Naval Architects and Marine Engineers, March 1955.

sheered wales—heavy timbers running fore and aft on the outside of the frames—which made the decks at the ends difficult to walk on. In the north, except for a few widely spaced tie beams, the deck beams ended on the inside of the ship and the decks were run in at any level desired.

In spite of the interchange of shipbuilding knowledge during the period of the Crusades previously mentioned, certain of these distinctive features persisted until about the end of the fifteenth century. Northern shipwrights clung to their clinker planking but gave up the frame lashings and used wooden pegs, 'tree-nails,' for fastening the planking to the frames. With an increase in the size of ships, the southern builders found it more and more difficult to keep a tight joint around the protruding beam ends when the ships were strained in storms, and shifted gradually to the northern system of supporting the decks on the inside.

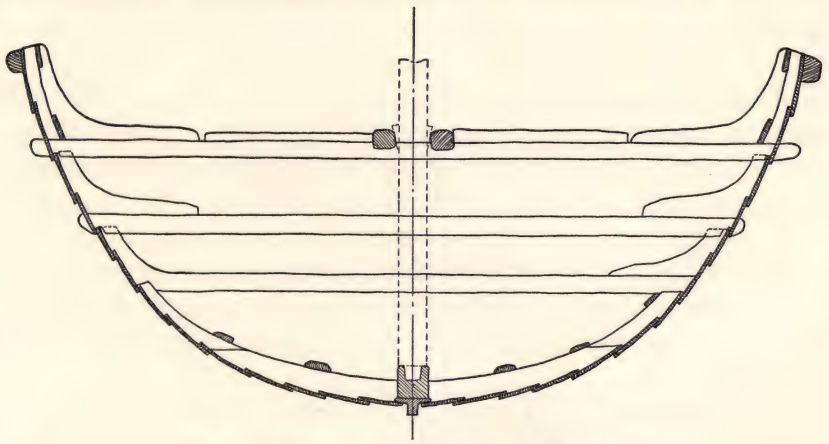

Fig. 3. Midsection—Kalmar Find I.
(After Akerlund—Fartygsfynden.)

Figure 3 is the midsection of a Swedish vessel that has been dated about the middle of the thirteenth century. It illustrates the general type of northern construction that persisted until the end of the seagoing clinker-built vessel, with frames notched for the planks and treenails employed for fastenings. This is based on one of a number of wrecks uncovered in the old harbor of Kalmar, Sweden, during the middle 1930's. This particular vessel was labeled Find I and measured about 36 feet in length, 15 feet in breadth, and had a depth of about 6½ feet amidships. It was constructed mostly of oak and was equipped with one mast and sail, a windlass located aft, and a stern rudder.[8]

8 Harald Akerlund, *Fartygsfynden i den Forna Hamna i Kalmar* (Stockholm: Sjohistoriska Samfundet, 1951).

The main transverse strength of the hull was provided by four sets of crossbeams similar to those shown. Note that the two upper beams protrude through the side and are notched to fit over plank edges. Normal frames were spaced about 18 inches apart. While this vessel is small in actual dimensions, considered in the light of the Swedish economy of the twelfth century, it can be classed as a typical medium-sized cargo vessel. The framing of Find XIV at Kalmar, which is assumed to have been sunk in the late seventeenth century, is essentially the same as that of Find I.

On 11 December 1416, King Henry V of England appointed a Clerk of Works for the building of a great ship which was to be the largest vessel constructed in England until the reign of Charles I, 1625-1649. This was *Gracedieu,* a ship of about 1,400 tons. No record of her dimensions has come down to us and at present there is no way of deducing them as there has been no successful explanation of medieval tonnage in modern terms.

Gracedieu was the climax of clinker-ship construction in England but she had a very uneventful career—in short, she was a failure. There is no record of a launching date but in July 1418 she was blessed by the Bishop of Bangor. A master and small crew were appointed for her safekeeping but it was apparent that she was not seaworthy and no money was spent for decorative painting, carvings, or flags. Her only recorded voyage, made some time after her blessing, was from Southampton to the Hamble estuary near Bursledon where she remained afloat for twelve years. Her final move from the estuary was further up the river to ground on the mud where, on the night of 6 January 1439, she was struck by lightning and burned.[9]

While *Gracedieu* was a failure, other vessels of the same type that measured about 1,000 tons were in active service and it is probable that they all had the same type of construction. The wreck of *Gracedieu* was thoroughly investigated between 1933 and 1936 and showed an amazing type of construction. Although considered to be of the clinker type, it was nothing simple like the earlier smaller craft. Each 'plank,' 6 to 7 feet in length, was built in three layers. The two outer layers were 12 inches wide while the third was 8 inches, arranged as shown in Figure 4 to give a lap of 4 inches. Round-headed nails, 5/8 inch square, passed through the five layers at the laps and were clenched over iron roves on the inside; these nails were spaced 6 to 8 inches apart.[10]

The framing is as unusual as the planking. The remaining frames are

9 Mrs. W. J. Carpenter Turner, 'The Building of the *Gracedieu, Valentine,* and *Falconer* at Southampton, 1416-1420,' *The Mariner's Mirror,* Vol. 40 (1954), 55-72.

10 Sir Westcott Abell, *The Shipwright's Trade* (Cambridge: At the University Press, 1948), pp. 20-22.

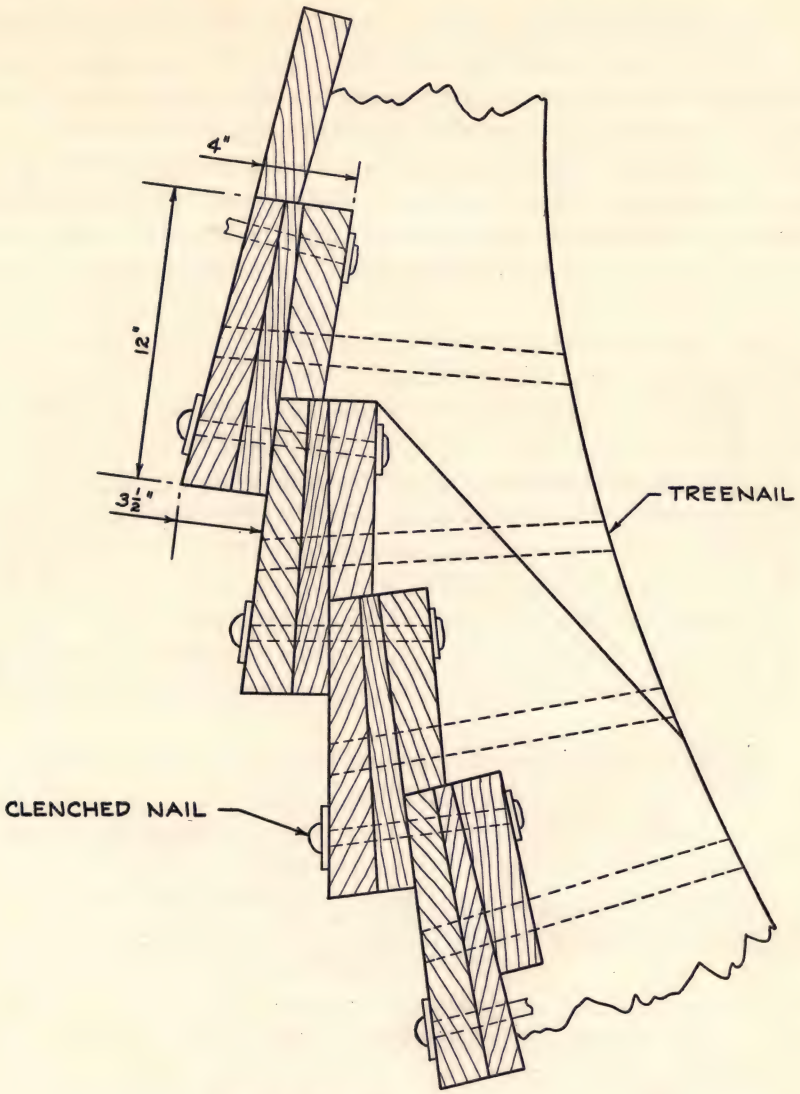

Fig. 4. Planking of *Gracedieu.*
(After Abell—Shipwrights trade.)

sided 12 inches, i.e., the width along the planking; and molded 10 inches, i.e., the depth, and are spaced so that there is but 4 inches between them. They are notched to fit the planking and are fitted in short lengths with scarphs parallel to the planking. The planks are secured to the frames with treenails, one in the middle of each plank. Considering the spacing of the clenched nails, the spacing of the notched frames, and the type of

scarph, it is apparent that the frames were inserted after the planking was erected. Some sort of molds on which to erect the planking must have been employed during her construction but the exact method of building such a clinker-planked vessel is liable to remain a mystery.

For an example of typical southern construction one must turn to a find on a completely different scale—a votive model from a small chapel in the town of Mataro on the coast of Caralonia in Spain. Competent authorities believe it to be a contemporary model of a Spanish vessel of the

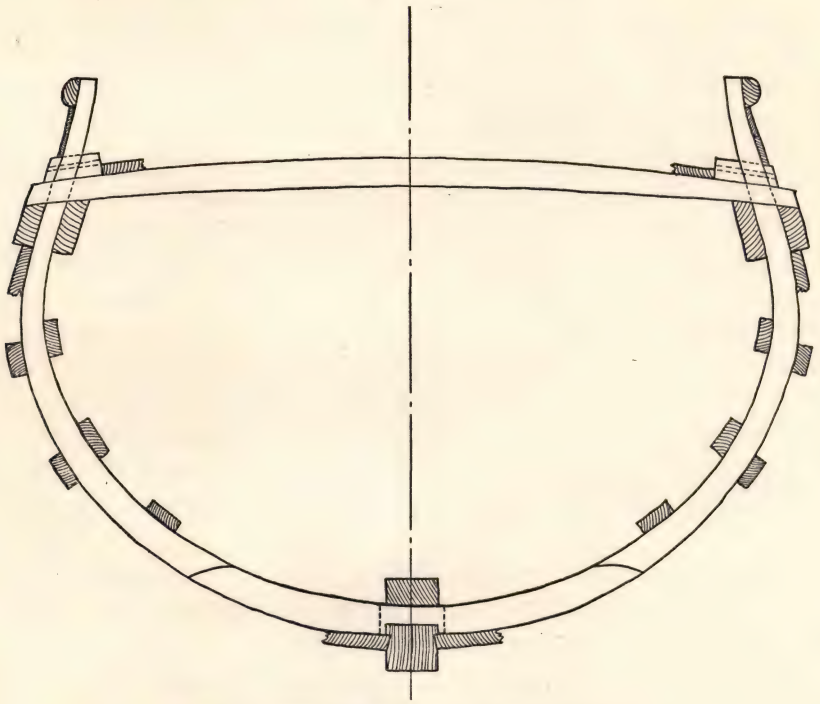

Fig. 5. Midsection—Spanish caravel.

early or middle fifteenth century and have called it 'the most interesting of all ship models.' In contrast to the majority of old votive models that are the carved-block type, this unnamed model is completely built up. Thus many items in pictorial representations of fifteenth-century ships have been explained and, on the other hand, hitherto disputed art works have been corroborated.[11]

Figure 5 is a rough midsection based on a detailed description of the

[11] Henry B. Culver, 'A Contemporary Fifteenth Century Ship Model,' *The Mariner's Mirror,* Vol. XV (1929), 213-221. J. W. van Nouhuys, 'The Model of a Spanish Caravel of the Beginning of the Fifteenth Century,' *The Mariner's Mirror,* Vol. XVII (1931), 327-346.

model, photographs, and an outline from an old Italian manuscript. Notched over the keel is a heavy floor timber and fixed to the forward side of this is the actual frame that in the model runs in one piece from the centerline to the deck. In an actual ship there were probably two or more pieces scarphed together similar to the frames of Kalmar Find I. Shown on top of the floor is a heavy keelson and there are three stringers on each side above the bilge. The beams of the single deck are supported by a heavy clamp on the inside and a wale outside.

The first half of the sixteenth century was the era of the 'great ship.' Each important maritime nation and city-state seems to have had at least one, usually as a bolster to national pride. There was the English *Henry Grace a Dieu,* the Scottish *Great Michael,* the French *Grand Francois, Santa Ana* of the Knights of Malta, the Portuguese *Sao Joao,* and Lubeck's *Der Grosse Adler,* to name a few. The northern vessels of this group were usually called carracks or caravels while the southern were listed as galleons. Although there were probably certain national peculiarities in the construction of these vessels, it can be assumed that in general they were of the standard construction evolved from the mingling of the northern and southern characteristics—a heavy frame, smooth planking, and decks supported wholly on the inside so they were independent of the sheer of the wales.

The Swedish *Elefanten,* built in 1554, was one of these 'great ships.' She was badly damaged in a Baltic Sea battle in 1564 and sank off the harbor of Kalmar while trying to reach port. Attempts were made at that time to float the ship by the use of a number of smaller vessels but they all failed. Further attempts between 1933 and 1939 to recover a portion of the wreck were successful and the stern structure is now on display in the Sjöhistoriska Museet in Stockholm.[12]

A typical detail of the framing and planking of *Elefanten* is shown in Figure 6; it is almost what would be called today 'seam batten' construction. The frames of nearly square section are hewed natural crooks with vertical scarphs, i.e., scarphs perpendicular to the planking in contrast to the parallel or horizontal type in *Gracedieu* and Kalmar Find I. Under each seam between the frames is fitted a narrow piece of wood as a backing strip which the frames are notched to receive. The strakes of planking are about 10 inches wide and are secured to the frames with treenails. Between each two strakes of planking up to the turn of the bilge are fitted wales about half the width of the planks, five in all on each side. These are through bolted to the frames.

12 ——— 'Stora Kraveln *Elefanten,*' Svenska Flottans Historia (Malmo, 1942), pp. 89-98.

While the midship portion of *Elefanten* was not excavated, a section near the stern shows nearly all the structural members that are found in later wooden ships. There is, of course, a substantial keel but the keelson, while of the same breadth, has but one-third the depth of the keel. The

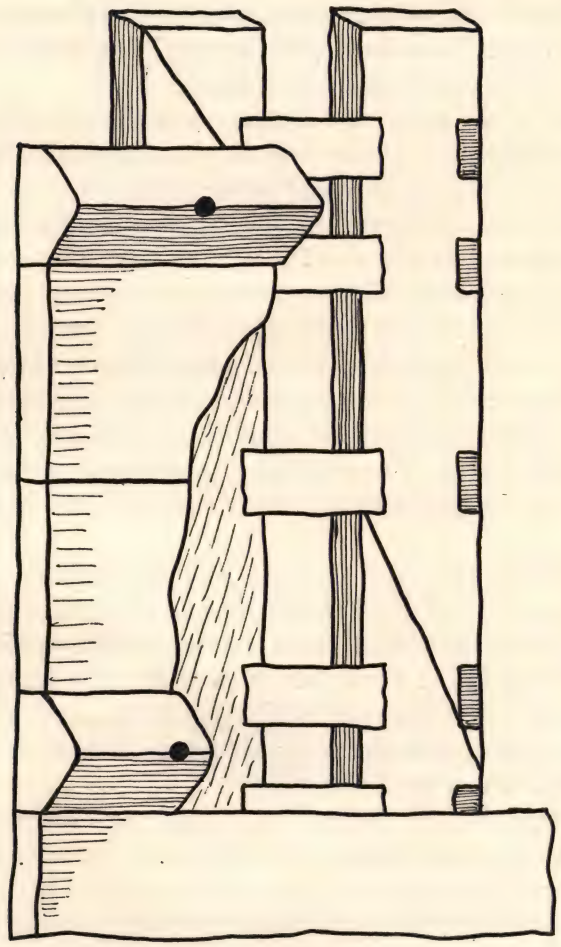

Fig. 6. Planking of *Elefanten.*
(After Svenska Flottans Historia.)

interior has a full ceiling. The beams of the lowest of three decks rest on frame riders, heavy transverse timbers fitting inside the ceiling; clamps support the beams of the two higher decks. A complicated arrangement of frame riders and hanging knees lapped on to these beams secure them to the ship's side. To strengthen the decks there are two or more heavy

strakes of planking on each side of the centerline that are notched down over the beams.

Structural midsection drawings in Mathew Baker's notebook give no hint as to the method of fabricating the frames nor do they show the thicknesses of the planking or ceiling. Figure 7 shows the most complete section in this notebook, that of a large three-deck ship. From the scale on the

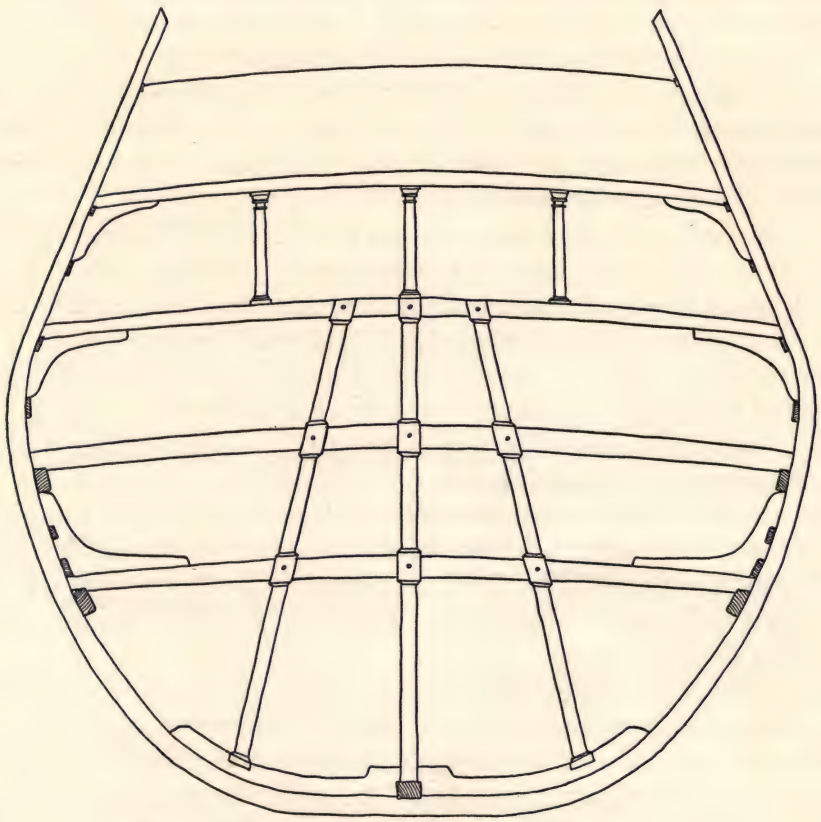

Fig. 7. Midsection—sixteenth-century galleon.
(After Mathew Baker.)

original drawing it is assumed to be for a proposed vessel with a miximum breadth of about 47 feet; the maximum recorded breadth of any of the ships of Queen Elizabeth I was 40 feet.

In this as in other sections in the notebook, the frame is shown tapering evenly from the keel to the head, where the molded dimension is slightly more than half that at the keel. Deck beams are tapered from the centerline out to the side where they are supported on clamps. The beam on

the highest of the three main decks has hanging knees fitted under the ends, the middle deck has no knees, while the lowest has standard knees on top of the beam. A heavy floor rider serves as a step for one centerline and two unique inclined stanchions supporting all three decks. One superstructure deck supported by three light pillars is shown.

Some idea of the scantlings of a medium-sized ship of this period can be had from a Dutch contract of 1583. The keel, 58 feet in length, was to be 14 inches square, of two pieces with a 6-foot-long scarph. The curved stem was to be in one piece, scarphed on to the keel, with a 12-foot forward rake and a convexity of 4 feet. It was to be 15 inches wide on the inner face and 7 inches on the outer. The sternpost was the same size as the keel with the main transom 15 inches square. A keelson 22 inches wide and 8 inches thick was to be fitted.[13]

The dimensions of the frames are not given but the floors were to be 11 inches deep and 8 inches wide. The garboard strake and the next strake above were to be 3 inches thick while the remainder of the planking and the ceiling were to be 2½ inches thick. Ordinary deck beams were to be 12 inches square with one mast beam 15 inches square; these were to be supported by clamps 3½ inches thick by 18 inches wide. A 22-inch-wide and 4½-inch-thick waterway was to be fitted on the weather deck with deck planking of 2-inch-thick oak.

The breadth of this vessel was to be 23 feet but no depth was given in the contract. The overall length of such a vessel was roughly the keel length plus the breadth, in this case about 85 feet. Many of the corresponding scantlings of a modern 89-foot overall vessel are not too different from those listed above.

Four or five of the twenty-five wrecks uncovered in the harbor of Kalmar were sunk during a war in 1611. Several others were sunk during the middle and last parts of the seventeenth century. Of these twenty-five wrecks only one had carvel planking, the others being clinker-built, differing but little from the basic construction of Find I previously described. There are indications that clinker construction was the standard method for most small and some medium-sized vessels in the northern countries up to about 1625. The carvel-built vessel was the revenue cutter *Krakan,* Find XII, which sank in 1651. The keel was about 45 feet in length and was in two thicknesses, the upper having rabbets for the garboard strakes. The hull was double planked, the inner being of oak and the outer of pine, both about 1½ inches thick. The framing was comparatively light and irregularly spaced. There were definite floor tim-

[13] R. C. Anderson, 'Details of a Dutch Ship of 1583,' *The Mariner's Mirror,* Vol. 13 (1927).

bers extending over about four planks on each side of the keel. Only the first futtocks remained of the rest of the framing and these were lapped about 1½ feet along the floors but apparently not fastened to them. The futtocks were lapped abaft the floors on the starboard side of the vessel and forward on the port side.

A development of this type of framing appears in the remains of *Sparrow-Hawk,* a small English vessel wrecked on Cape Cod in 1626; these remains are now exhibited in Pilgrim Hall, Plymouth, Massachusetts. When complete, *Sparrow-Hawk* had a keel length of about 28 feet 10 inches, an overall length of about 40 feet, a breadth of about 12 feet with a depth of about 9½ feet. The following description of her construction is taken from the report of Dolliver & Sleeper, shipbuilders of Boston, who supervised the assembly of the remains after they were dug from the Orleans marsh in 1863.[14]

> Her keel is of English elm, twenty-eight feet six inches long, sided eight inches and moulded six; the floor timbers amidships are seven feet one inch long, moulded seven inches and sided six, all of oak hewn square at the corners and fastened through the keel with one-inch oak treenails wedged in both ends. The first futtocks overlap the floor-timbers about two feet, placed along side of them, forming almost solid work on the turn of the bilge, with a glut or chock below each of them, but they were not fastened together. She has not any navel timbers. We suppose that the joints of the second futtocks overlapped in the same style as those below them. As already stated, her stem and forefoot are gone; but a part of her sternpost, and her stern-knee entire, are left. The sternpost is mortised into the keel, and has been bolted through it and the knee; but the iron has been oxidized long since. Instead of deadwood aft she has seven forked timbers, the longest four feet in the stem, with a natural branch on each side, and six inches square. Some of these were half fayed to the keel, but none of them were fastened. Through these the planking was treenailed. Part of the keelson is now in its place; it is sided ten inches and moulded eight, and was fastened to the keel with four iron bolts, driven between the floor-timbers (not through them) into the keel.

While the above type of framing may seem strange, it is not an isolated example, as it is corroborated by what is perhaps the first English marine dictionary, that by Sir Henry Mainwaring.[15] This was first published in 1644 but existing manuscript copies show that it was compiled between 1621 and 1623. This work and 'A Sea Grammar' by Captain John Smith list nearly all the structural members found in modern wooden vessels. Their names and arrangement may be different, but they are there.

[14] H. H. Holly, '*Sparrow-Hawk,* A Seventeenth Century Vessel in Twentieth Century America,' THE AMERICAN NEPTUNE, XIII (1953), 51-64.

[15] Sir Henry Mainwaring, 'The Seaman's Dictionary,' in G. E. Manwaring and W. G. Perrin, *The Life and Works of Sir Henry Mainwaring* (London: The Navy Records Society, 1922), II, 69-260.

Smith, in another work titled 'An Accidence, or The Pathway to Experience for all Young Seamen,' dated 1626, describes the building of a ship as follows:

> First lay the Keele, the Stemme, and Starne in a dry docke, or uppon the stockes, and binde them with good knees; then lay all the Flore timbers and cut your limber holes above the keel to bring the water to the well for the pumpe. Next your Navell timbers and binde them all with a six foot Skarfe at the least. The Garbell strake is the outside strake next the keele. Be sure you have a good sufficient Kelson: then planke your outside and inside up, with your Top timbers; but the lengthes, breadths, depthes, rakes and burdens are so variable and different that nothing but experience can possibly teach it.
>
> A Shippe of 400 Tunnes requires a planke of four inches; 300 Tunnes, three inch; small Ships, two inch; but none less. For clamps, middle bands and sleepers, they be all of 6 inch planke for binding within. The rest for the sparring up of the workes of square 3 inch planke.
>
> Lay the beames of the Orlope, if she be 400 Tunnes at ten foote deepe in the howle, and all the beames to be bound with two knees at each ende, and a standard knee at every beames end upon the Orlope: all the Orlope to be layd with square three inch planke, and all the plankes to be treenailed to the beames.
>
> Six foote would be between the beames of the Decke and Orlope, and ten ports on each side uppon the lower Orlope: all the binding between them should be with three inch, or two inch planke, and the upper Decke should be layd with so many beames as are fitting with knees to binde them: laying that Decke with spruce deale of 30 foot long, the sap cut off and two inches thick, for it is better than any other.

A few words of explanation will serve to make the above a little more intelligible. It is difficult to find a good explanation of a 'Navell timber' but it appears to be an extra futtock extending across the keel and bolted to the floor. This was really a doubling of the floor and probably added to strengthen the vessel for taking the ground as was, and still is, the custom for many English vessels to do at low tide. Sleepers were heavy fore-and-aft timbers on the inside of a vessel located on each side of the keelson at the junction of the floors and first futtocks. They were fastened to both the floors and the futtocks and were the only means of securing these in place other than the chocks mentioned in the description of *Sparrow-Hawk*. In vessels having two or more decks, only the uppermost was known by that term, the lower one or two being called orlops.

Other sources of information on the construction of ships of the early seventeenth century are the elaborate built-up models from England and the other maritime nations, the so-called Admiralty type. Such models were built primarily to show officials, who might be unacquainted with the details of ship construction, the appearance of a proposed new ship. The oldest of these date from about 1650 and are of fairly large war-

ships. They are so elaborately detailed in construction and decoration that they must have been preceded by simpler types.

The framing of the models constructed between 1650 and about 1700 is similar to that of *Sparrow-Hawk*. There is a floor timber running across the keel and what might be called either two futtocks or one futtock and a top timber on each side. These floors and futtocks have the same siding throughout the length of the model. The lower futtocks are fitted between the floors and extend upwards to a little above the lower-deck gun ports. Thus there is a solid band of timber at the bilge. Similarly, the second futtocks or top timbers, running from about the lower-deck level to the gunwale, are fitted between the first futtocks forming another and wider band of timber in way of the gun ports.

Nautical researchers believe that these models portray with reasonable accuracy the forms of the ships they represent but there is disagreement concerning the type of framing in spite of all the detail shown. Manuscript scantling tables for English ships of about 1685 list the sizes for four futtocks and a top timber, all tapering slightly in siding as they progress up the side. French drawings of about 1660 show the same number of pieces yet a Dutch drawing dated 1648 indicates structure like the models although quite irregular. A vessel constructed with four futtocks and a top timber would show five nearly solid bands of timber as compared with the two of the models.

It is believed by some that the models do represent the actual construction of moderate-sized ships up to about 1600 when timber supplies, particularly natural crooks, were plentiful. As ships grew in size and timber became scarcer, the ship frame had to be built up of a greater number of shorter lengths. However, a school of model building had been established based on the single futtock and top timber system and this was continued as it represented the way a ship would have been built had suitable timber been available. In addition, the model looked neater and there were fewer pieces to assemble.[16]

Based on the foregoing details of ship construction, it can be assumed that a typical medium-sized English ship of the early seventeenth century would have had smooth planking. It can also be assumed that the frames could have had horizontal scarphs similar to the Kalmar vessels, vertical scarphs like *Elefanten,* or lapped futtocks like *Sparrow-Hawk*. Inasmuch as the framing of the *Mayflower* replica will be concealed by the ceiling and in consideration of modern timber supplies, strength requirements, and other factors, it was decided that the framing of the replica would follow

[16] W. Salisbury, 'The Framing of Models,' *The Mariner's Mirror,* Vol. 40 (1954), 156-159.

none of these. Instead, it will be of the modern double-sawn futtock type, that is, each frame will be constructed of a number of short overlapping sections each having half the thickness of the whole frame. The midsection for the proposed replica is shown in Figure 8.

To show how an early seventeenth-century ship might have been constructed, it was decided to build an Admiralty-type model for display in

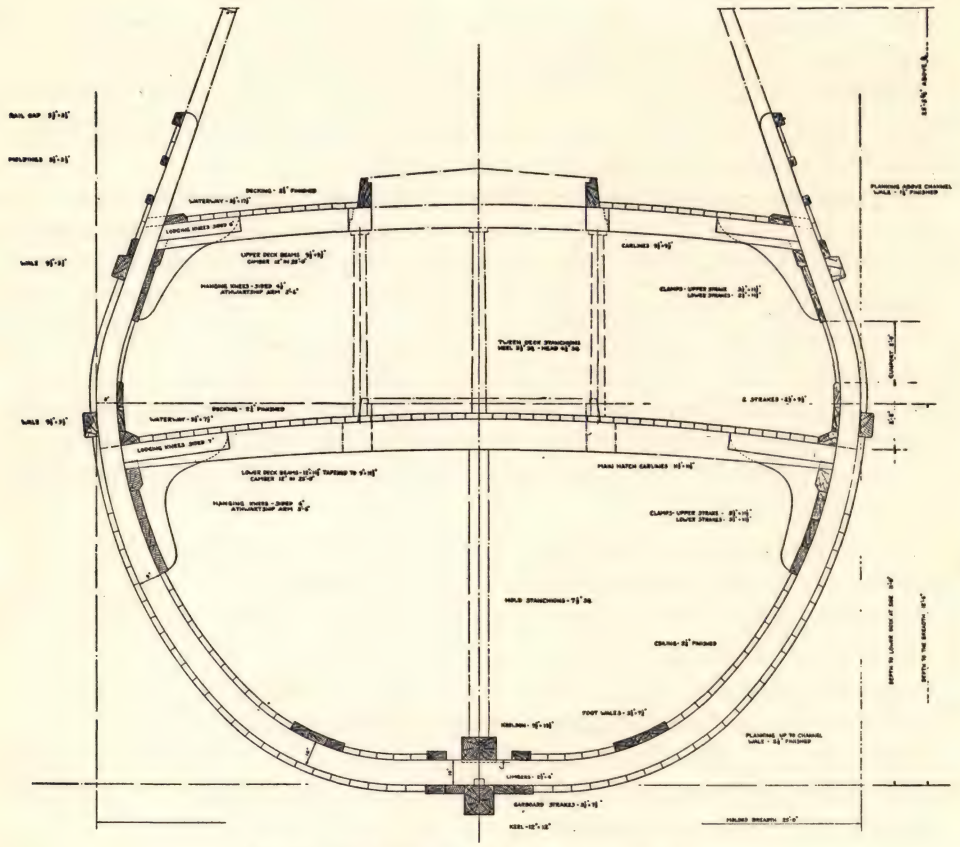

Fig. 8. Midsection of *Mayflower* replica.

connection with the replica. To save plan work, this meant that the structural plans for the decks should be suitable for one of the old types of framing mentioned above as well as for modern-type framing. A study of this problem led to the choice of the *Sparrow-Hawk* type with lapped futtocks for this model.

The simplest way to describe some of the fittings and details of the proposed replica is to take the reader on an imaginary tour of the ship. Omit-

ting the process of getting aboard and staying out of the hold, the tour can start on the lower deck at the very bow. Here is found the manger, a wooden bin built from side to side under the hawse holes to collect water that might come in through them. Looking aft from here there is the impression of a six-foot-high tunnel stretching some 75 feet back to the stern with the hanging knees of the upper deck beams cutting off the sides. Immediately abaft the manger is the foremast with the bowsprit coming in on the starboard side. This area around the foremast is a bit cluttered, for just abaft it are the heavy riding bitts, port and starboard, and a companion ladder going up to a small hatch in the upper deck. The anchor cables are normally stored in the hold being passed down through a small hatch abaft the riding bitts.

The mainmast stands slightly abaft the mid-length of the lower deck and just forward of it is the main cargo hatch with a low coaming. Thus from the riding bitts to the mainmast there is a fairly clear space about 26 feet in length and about 22 feet in width with a few light pillars supporting the upper deck. In normal operations, some non-perishable cargo was probably carried in the space. Abreast the mainmast, port and starboard, are the ship's pumps, for this lower deck is actually the watertight one. Lead pipe scuppers with outside leather covers are provided along the deck to drain the water overboard; similar scuppers are fitted in the manger. Chain pumps were invented during Queen Elizabeth's reign but were probably fitted only on the larger ships. The pumps on this ship are of the old bored log variety with long wooden handles.

About 10 feet abaft the mainmast stands the double capstan with its spindle about the same diameter as the mainmast; it extends above the upper deck where bars may be fitted, too. The capstan is used primarily to weigh the anchors but also serves to hoist the yards and any special lifts including cargo. Above the gun ports in the stern are cut two small holes called 'cat-holes,' through which lines may be led to the capstan when it is necessary to haul the ship astern.

The step in the lower deck is about 12 feet forward of the stern and below this in the hold is a bulkhead. The compartment thus formed under the lower portion of the deck is the powder magazine and there is a small hatch leading down to it. The after part of the main hold is used for the ship's stores and there is a stores hatch just forward of the break in the deck.

On this deck, there are guns in the two stern ports but although there are four ports cut in each side of the ship, only two per side have guns in keeping with the known crowded condition of the ship. Four more guns

are carried on the upper deck. Ordnance types of the early seventeenth century had fanciful names and there was considerable variance between pieces of the same type. The largest type in general use on shipboard was a demi-cannon, a piece about 10 feet long of 6½-inch caliber weighing about 6,000 pounds. However, smaller pieces such as culverines of 5½-inch caliber, demi-culverines of 4½-inch caliber, and sakers of 3½-inch caliber were more common as they could be served more quickly and, on a warship, a heavier broadside fire could be carried in the same space. On a merchant vessel, perhaps even smaller pieces such as minions of 3¼-inch caliber and falcons of 2-inch caliber were carried.

Coming in through a stern port over the main transom beam is the tiller, supported near its forward end by a light transverse beam and terminating in an iron pin. Passing through a roller fitted in the upper deck is a vertical staff—the whipstaff—that has at its lower end an iron ring which fits over the pin on the tiller. Going up through a hatch in the upper deck located over the stores hatch in the lower deck one enters the steerage where the helmsman stands abaft the upper end of the whipstaff. Forward of the whipstaff is the binnacle, a small wooden cabinet that holds the compass, candles to light it at night, and the sand glasses. Normally, the ship is balanced on her course by the sails and the helmsman corrects only minor variations in compass headings with the whipstaff. Through a small hatch overhead in the half deck he can see the sails on the mainmast and also receive orders from an officer on deck. On some small ships, the helmsman stood on a raised platform with his head and shoulders above the half deck—a small shelter protected him from the weather.

The great cabin at the stern on the upper deck is entered through a door on the starboard side and there is a slight break in the deck here to make this cabin as spacious as possible. Stepped on the centerline at the forward end of the cabin is the mizzenmast. Although when the Pilgrims were aboard this cabin was probably cluttered with a number of built-in bunks, the normal fittings would have been quite simple. Against the after end beneath the three stern windows there is a built-in settee with a bolted-down table in front of it. Other furniture, built in, would be a berth with drawers under on the port side forward and a cabinet to hold books, the crude charts, and the simple navigating instruments. A lamp or two, a bench, and a musket and cutlass hanging on the bulkhead would complete the equipment.

Going forward from the helmsman's station one finds the upper part of the capstan previously mentioned and then the mainmast again. Just abaft the mast and slightly to starboard is a vertical timber about 12 inches

square extending about 4 feet above the deck and fitted with four sheaves. This is the main knight which serves as the lower block for the main halliard. Similar knights are fitted at the fore and mizzenmast.

Between the mainmast and the forecastle is a long hatch of the same width as the cargo hatch in the lower deck that is known as 'the gratings.' The normal hatches such as those in the lower deck are fitted with loose wooden covers and are made watertight by tarpaulins secured with lashings. The companion hatches in the upper deck would have portable gratings and perhaps covers, too, that could be fitted if necessary. Apparently 'the gratings' were nothing more than the name implies—a series of gratings supported by strong beams that were only covered in very foul weather by a tarpaulin. Their purpose appears to have been to provide light and air to the 'tween-deck space. The ship's boats were usually stowed on 'the gratings.'

Passing into the forecastle through a double door on the centerline, the upper deck companion hatch is to starboard, as previously noted, and the galley is to port 'especially being contrived in furnaces for the saving of wood in long journeys.' [17] The fore knight stands a little abaft the mast to port of the centerline; a small opening in the forecastle deck is provided for the halliard to pass. Doors are fitted port and starboard in the forward forecastle bulkhead to give the crew access to the beakhead.

Going aft again and climbing one of the ladders fitted to port and starboard of the mainmast one comes on to the half deck. A short length of portable grating at the forward end makes it possible to haul out and replace the capstan spindle should it get badly worn or broken. At the stern on this deck is the so-called 'master's cabin' with its door to starboard and a ladder to the deck above on the port side. This cabin is sparsely furnished with a built-in berth and a small bench. Small windows, one in each side and one in the bulkhead provide light. Just forward of the bulkhead stands the mizzenmast with its knight on the centerline forward of it. There is enough space between the mast and the bulkhead to allow the lateen mizzen yard to swing between them as it is shifted to the leeward side of the mast when the ship is tacked.

In spite of the work of many researchers, there are still many uncertainties concerning the masting and rigging of early seventeenth-century ships. The general pattern is set by old prints and it is found that the standard rig for all sizes of seagoing vessels was a three-masted one—square sails on fore and mainmasts, a lateen-rigged mizzen, and a square spritsail under the bowsprit. Representations of two-masted square-

[17] Sir Henry Mainwaring, op. cit., pp. 131-132.

rigged vessels—even small ones—are uncommon until much later in the century. There were, however, some vessels with two masts carrying various combinations of square and fore-and-aft sails, forerunners of the ketch rig; *Sparrow-Hawk* is assumed to have had a two-masted rig of this type. A few of the large ships had four masts, three rigged as noted above while the fourth was another lateen located high on the poop.

Three contemporary sources were used in working out the sizes of the masts and spars for the proposed replica—Mathew Baker's notebook, a manuscript in the library of the Institution of Naval Architects,[18] and Mainwaring's dictionary. The following table lists the sizes according to these sources and those chosen for the replica:

		Mathew Baker	*I.N.A. Ms.*	*Mainwaring*	*Replica*
Mainmast	l	71′-3″	67′-6″	60′-0″	67′-6″
	d	22¼″		20″	20½″
Main topmast	l	30′-9″	33′-9″	30′-0″	33′-9″
	d	9¼″		10″	9″
Foremast	l		57′-10¼″	48′-0″	57′-9″
	d	18¼″		16″	17″
Fore topmast	l	26′-3″	28′-11⅛″	24′-0″	29′-0″
	d	7¼″		8″	7½″
Mizzenmast	l			30′-0″	41′-8″
	d	11¼″		10″	10½″
Bowsprit	l		57′-10¼″	48′-0″	57′-9″
	d	14½″		16″	13½″
Main yard	l	58′-6″	54′-0″	48′-4″	54′-0″
	d	14¼″		12″	13½″
Main topsail yard	l	19′-6″		20′-8½″	21′-6″
	d	4⅞″		5¼″	5⅜″
Foreyard	l	43′-6″	40′-6″	38′-8″	40′-6″
	d	11″		9⅝″	10″
Fore topsail yard	l	14′-7½″		16′-7″	16′-3″
	d	3⅝″		4⅛″	4⅛″
Mizzen yard	l		40′-6″		40′-6″
	d				7½″
Spritsail yard	l	32′-7½″	30′-4½″		30′-4½″
	d	8¼″			6¼″

[18] Anonymous Ms., 'A Most Excellent Mannor for the Building of Shippes,' Scott Collection, Institution of Naval Architects, London. By courtesy of the Institution of Naval Architects.

For the rigging of the replica, a contemporary treatise[19] and Mainwaring's dictionary provided the basic material which was supplemented by the published works of Miller, Moore and Anderson.[20] The minutiae of what leads where and why, how many of each, and so forth, are of primary interest to but a handful of nautical researchers and will not be discussed here. In fact, they can hardly be covered properly in much less than a book. One of the most bothersome problems was the determination of the sizes and details of the miscellaneous fittings. They can not be ordered from a manufacturer's catalogue nor can they be carved from a small piece of wood to an approximate shape as is usually satisfactory for a model. For many, it has been possible to base the design on actual seventeenth-century samples found in old wrecks.

Now take the brief description of the arrangement of this proposed replica given above and add to the fittings noted on the weather decks the multitude of cleats and kevels for securing the running rigging with coils of rope on each. Place on board one hundred and two assorted Pilgrims and colonists, plus a crew of about twenty-five. Stow in the hold all the necessary goods for founding and maintaining a colony for a considerable period. Clutter up the 'tween-deck space with a cut-down shallop. Add cold weather, cold water dripping on all through leaking decks and topsides and toss liberally around the North Atlantic for two months. Season the situation with the inevitable difficult relations among a large group living in confined spaces. When the ship is at last riding safely at anchor off the tip of Cape Cod, one cannot help but admire the courage and fortitude of the little band whose condition is best described by Governor Bradford:[21] 'But here I cannot but stay and make a pause, and stand half amazed at this poor people's present condition; and so I think will the reader, too, when he well considers the same. Being thus passed the vast ocean, . . . they had now no friends to welcome them nor inns to entertain or refresh their weatherbeaten bodies; no houses or much less towns to repair to, to seek for succour.'

19 Anonymous Ms., 'A Treatise on Rigging,' Occasional Publications No. 1, The Society for Nautical Research, 1921.

20 Thomas Miller, *The Complete Modellist* (London, 1667). Alan Moore, 'Rigging in the Seventeenth Century,' *The Mariner's Mirror,* Vols. II, III and IV (1912, 1913, 1914). R. C. Anderson, *The Rigging of Ships in the Days of the Spritsail Topmast, 1600-1720* (Salem: Marine Research Society, 1927).

21 William Bradford, *Of Plimoth Plantation,* printed by order of the General Court (Boston: Wright & Potter Printing Co., State Printers, 1899), pp. 94-95.

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